HARPETH RIVER WATERSHED MODELING EFFORT:
A Tool for TMDL Development

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EPA United States Environmental Protection Agency

Region 4 serving the southeast

Executive Summary

As part of a Settlement Agreement requirement, the U.S. Environmental Protection Agency (EPA) is responsible for developing a water quality model by July 31, 2002 to be used as part of the Total Maximum Daily Load (TMDL) process to address the organic enrichment/dissolved oxygen impairment of waters in the Harpeth River watershed in Tennessee. In order to meet this requirement, EPA has developed a system of four models which include: 1) an application of the watershed model, Loading Simulation Program in C++ (LSPC), to the Harpeth River watershed as defined by the hydrologic unit code 05130204; 2) an application of the steady-state, one-dimensional dissolved oxygen model, QUAL2E, to the upper portion of the mainstem of the Harpeth River (i.e., upstream from River Mile 89.2); 3) an application of the one-dimensional, hydrodynamic model CE-QUAL-RIV1 to the lower portion of the mainstem of the Harpeth River (i.e., from River Mile 88.1 to 32.4); and 4) a linkage of the Water Quality Analysis Program (WASP) 6.0 eutrophication model with the CE-QUAL-RIV1 hydrodynamic model.

These modeling tools were parameterized and, to the extent possible, calibrated using available data. A significant amount of data used in the modeling effort was collected during intensive water quality studies conducted in 2000 and 2001. The Tennessee Department of Environment and Conservation has provided EPA significant support in the model development effort and intends to use the models as tools to develop and propose a TMDL for the Harpeth River watershed by December 31, 2002. EPA welcomes any interested parties to submit comments on any aspects of the modeling effort by September 30, 2002. These comments will be considered as part of the TMDL process.

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Introduction

This report documents the development of water quality models that will be used as tools for establishing Total Maximum Daily Loads (TMDLs) to address the organic enrichment/dissolved oxygen impairment of waters in the Harpeth River watershed in middle Tennessee (see Figure 1). These modeling tools include: 1) an application of the watershed model, Loading Simulation Program in C++ (LSPC), to the Harpeth River watershed as defined by the hydrologic unit code (HUC) 05130204; 2) an application of the steady-state, one-dimensional dissolved oxygen model, QUAL2E, to the upper portion of the mainstem of the Harpeth River (i.e., upstream from River Mile 89.2); 3) an application of the one-dimensional, hydrodynamic model CE-QUAL-RIV1 to the lower portion of the mainstem of the Harpeth River (i.e., from River Mile 88.1 to 32.4); and 4) a linkage of the Water Quality Analysis Program (WASP) 6.0 eutrophication model with the CE-QUAL-RIV1 hydrodynamic model.

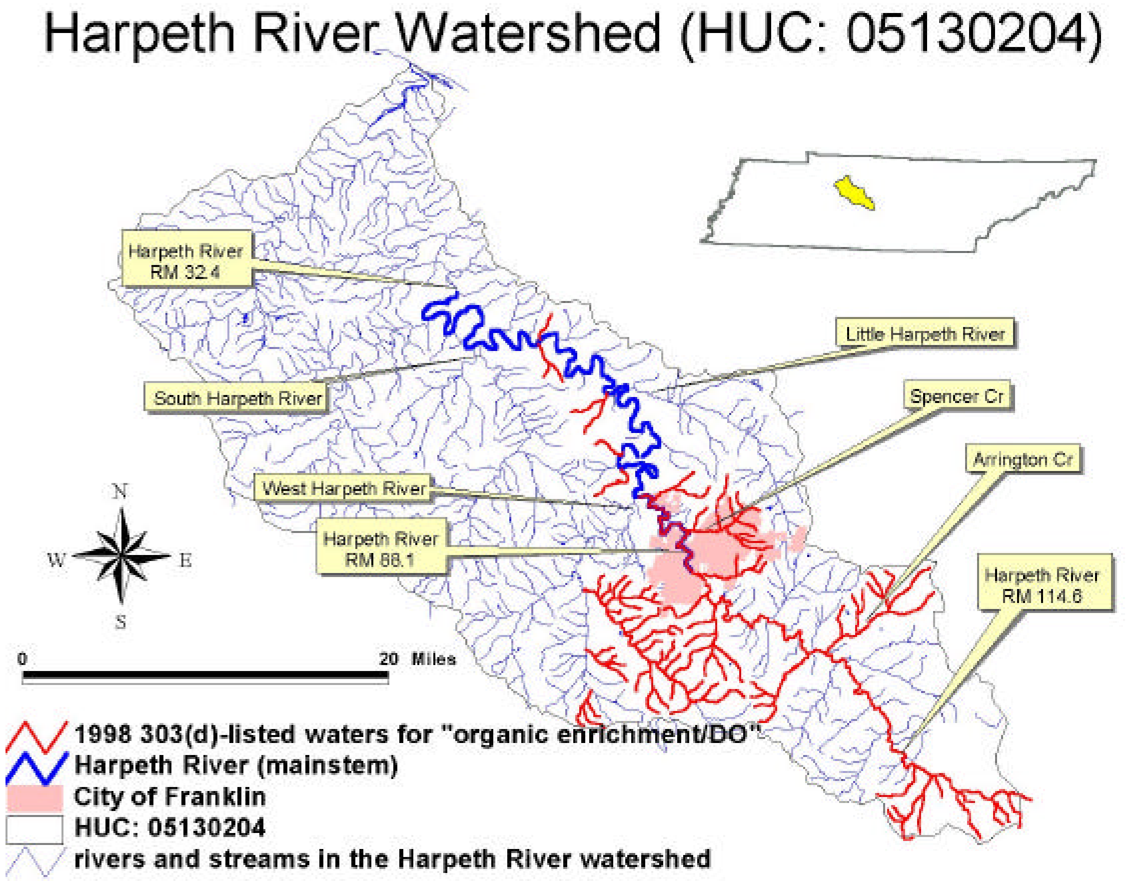


Figure 1. Harpeth River Watershed

General Watershed Description

The Harpeth River watershed is located in central Tennessee, south-southwest of Nashville, and includes parts of Cheatham, Davidson, Dickson, Hickman, Rutherford, and Williamson Counties. The 125-mile Harpeth River flows generally in a northwesterly direction before draining to River Mile (RM) 153 of the Cumberland River. The watershed has approximately 1,364 miles of streams and drains a total area of 867 square miles. The watershed lies within the Level III Interior Plateau ecoregion (i.e., ecoregion number 71) and contains three Level IV sub-ecoregions (see Figure 2), as defined by ecoregion classifications co-developed by the Tennessee Department of Environment and Conservation (TDEC), the U.S. Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS), and the U.S. Department of Agriculture's Natural Resources Conservation Service (USEPA, 1997). These Ecoregions are described as follows:

- Western Highland Rim (71f) is characterized by dissected, rolling terrain of open hills, with elevations of 400 to 1000 feet. The geologic base of Mississippian-age limestone, chert, and shale is covered by soils that tend to be cherty, acidic and low to moderate in fertility. Streams are characterized by coarse chert gravel and sand substrates with areas of bedrock, moderate gradients, and relatively clear water. The oak-hickory natural vegetation was mostly deforested in the mid to late 1800's, in conjunction with the iron ore related mining and smelting of the mineral limonite, but now the region is again heavily forested. Some agriculture occurs on the flatter areas between streams and in the stream and river valleys: mostly hay, pasture, and cattle, with some cultivation of corn and tobacco.

- Outer Nashville Basin (71h) is characterized as a relatively heterogeneous region and includes rolling hills. The region encompasses most all of the outer areas of the generally non-cherty Ordovician limestone bedrock. The higher hills and knobs are capped by the more cherty Mississippian-age formations, and some Devonian-age Chattanooga shale, remnants of the Highland Rim. The region's limestone rocks and soils are high in phosphorus, and commercial phosphate is mined. Deciduous forests with pasture and cropland are the dominant land covers. Streams are low to moderate gradient, with productive nutrient-rich waters, resulting in algae, rooted vegetation, and occasionally high densities of fish. The Nashville Basin as a whole has a distinctive fish fauna, notable for fish that avoid the region, as well as those that are present.

- Inner Nashville Basin (71i) is less hilly and lower than the Outer Nashville Basin. Outcrops of the Ordovician-age limestone are common, and the generally shallow soils are redder and lower in phosphorus than those of the Outer Basin. Streams are lower gradient than surrounding regions, often flowing over large expanses of limestone bedrock. The most characteristic hardwoods within the Inner Basin are a maple-oak-hickory-ash association. The limestone cedar glades of Tennessee, a unique mixed grassland/forest/cedar glades vegetation type with many endemic species, are located primarily on the limestone of the Inner Nashville Basin. The more xeric, open characteristics and shallow soils of the cedar glades also result in a distinct distribution of amphibian and reptile species.

Figure 2. Level IV Sub-ecoregions in the Harpeth River Watershed

The watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the landuse of the Harpeth River watershed have occurred since 1993 as a result of rapid development, this is the most current landuse data available. The landuse for the Harpeth River watershed is summarized in Table 1 and shown in Figure 3.

Table 1. Land Use Distribution in the Harpeth River Watershed

LAND COVER/LAND USE	AREA [sq. mi.]	AREA [%]
Open Water	3.43	0.4
Low Intensity Residential	16.16	1.9
High Intensity Residential	1.89	0.2
High Intensity Commercial /Industrial/Transportation	7.92	0.9
Bare Rock/Sand/Clay	0.00	0
Transitional	1.61	0.2
Deciduous Forest	433.89	50.0
Evergreen Forest	21.90	2.5
Mixed Forest	89.72	9.9
Pasture/Hay	203.69	23.5
Row Crops	76.65	8.8
Other Grasses (Urban/Recreational)	12.83	1.5
Woody Wetlands	1.18	0.1
Emergent Herbaceous Wetlands	0.02	0
Quarries/ Strip Mines/Gravel Pits	0.51	0.1
Total	867.39	100.0

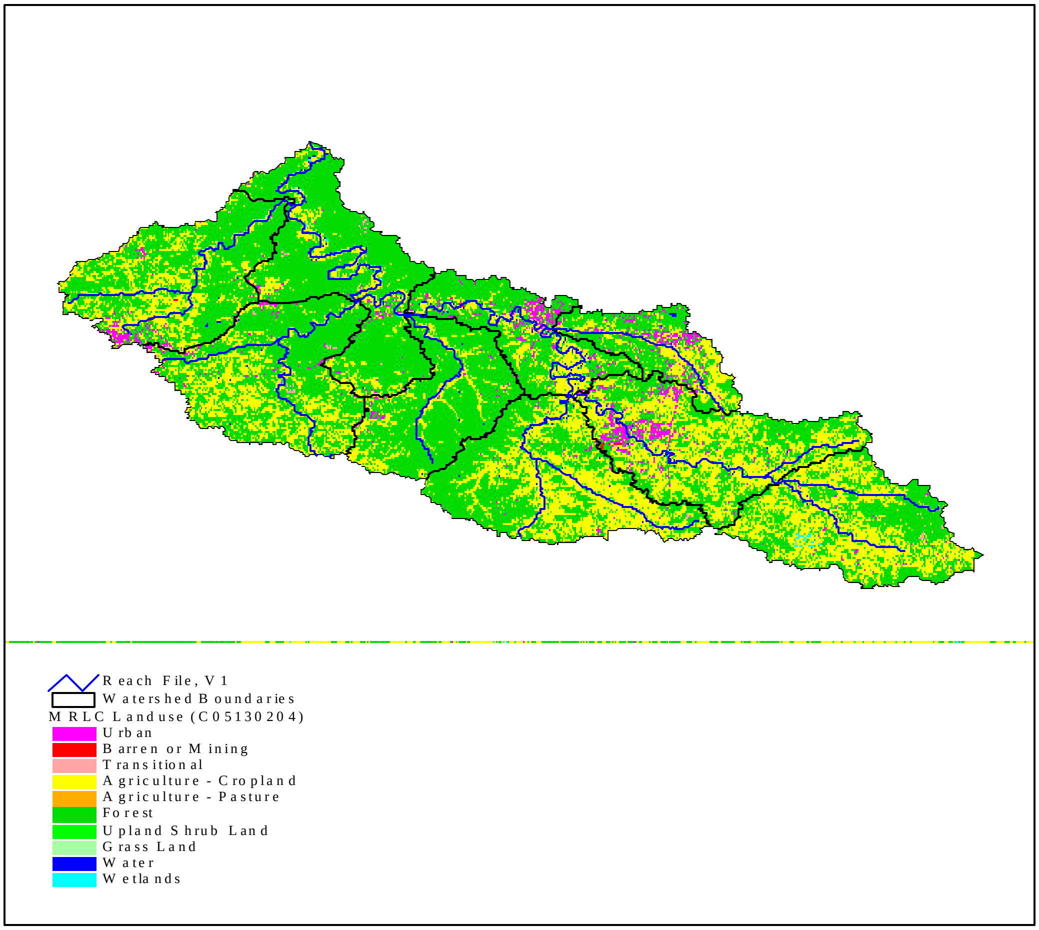


Figure 3. MRLC Land Use Distribution in the Harpeth River Watershed

§303(d) Background

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries (i.e., §303(d) list) for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those water bodies that are not attaining water quality standards. State water quality standards consist of designated use(s) for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources.

Table 2. Excerpts from TDEC's 303(d) List

Impacted Waterbody	CAUSE (Pollutant)	Pollutant Source	COMMENTS
HARPETH RIVER From W Fk Harpeth to headwaters is partially supporting	Org. enrichment/DO Siltation Habitat alteration Metals (As, Pb, Zn, Sb)	Agriculture Contaminated sediment Urb. Runoff/storm sewers Major Mun. Point Source Industrial Point Source	Impacts include Franklin STP. Legacy chemicals from General Smelting cause contaminated sediment upstream of Franklin
HARPETH RIVER TRIBUTARIES Arrington Cr, Spencer Cr, Watson Br, 5-mile Cr, Lynnwood Cr, and Starnes Cr	Org. enrichment/DO Siltation Habitat alteration	Agriculture Riparian loss	
HARPETH RIVER TRIBUTARIES Concord Cr, Puckett, Cheatham, Kelley, portion of Harpeth headwaters	Org. enrichment/DO Siltation Habitat alteration	Agriculture Riparian loss	Agriculture impacts near Eagleville
HARPETH RIVER TRIBUTARIES Newsome Cr, Trace Cr, and Murray Branch are partially supporting	Org. enrichment/DO Siltation Habitat alteration	Patureland Urb. Runoff/ storm sewers Riparian loss	
HARPETH RIVER TRIBUTARIES Beech and unn. Trib to Harpeth are not supporting	Org. enrichment/DO Siltation Habitat alteration	Riparian loss Urb. Runoff/ Storm sewers	
WEST FORK HARPETH RIVER A portion of West Harpeth, plus Cayce Branch, Polk, and Kennedy Creek are partially supporting	Org. enrichment/DO Siltation Habitat alteration	Riparian loss Pastureland	
W. FORK HARPETH TRIBUTARIES Rattlesnake Branch is not supporting	Org. enrichment/DO Siltation Habitat alteration	Agriculture	

The State of Tennessee Department of Environment and Conservation (TDEC) has identified several waters in the Harpeth River watershed as being impaired from the parameter “Organic enrichment/DO” on its 1998 §303(d) list. As part of a Settlement Agreement requirement, EPA Region 4 is responsible for developing a water quality model by July 31, 2002 to address the “Organic enrichment/DO” impairment for a subset of these waters. Specifically, EPA must address the subset of §303(d) listed waters that drain to the Harpeth River watershed upstream from the Sneed Road crossing of the Harpeth River at River Mile (RM) 66.0. These waters are listed in Table 2.

Concerning the §303(d) listing of waters in Tennessee, TDEC uses the term "Organic enrichment/DO" to describe impairment from: 1) low dissolved oxygen levels; 2) excessive eutrophication resulting from nutrient impacts; or 3) a combination of low dissolved oxygen levels and excessive eutrophication. As part of its §303(d) listing process, TDEC conducts assessments of its waters using water quality data, biological data, and field observation data concerning the presence or absence of excessive algae. For the first water listed in Table 1 (i.e., the Harpeth River from its headwaters to its confluence with the West Harpeth River), the §303(d) listing was based on low dissolved oxygen levels as well as biological assessment data that indicated stressed biota. Concerning all of the other waters in the Harpeth River watershed, the §303(d) listings were based on observations of stressed biota as well as the observation of excessive algae. For these waters there were no observations of low dissolved oxygen levels in the data that was used for the basis of the §303(d) listings.

Dischargers and Withdrawals

Several facilities permitted by TDEC's National Pollutant Discharge Elimination System (NPDES) program discharge wastewater to the impaired waters in the Harpeth River watershed. The five facilities that discharge organic loads (i.e., oxygen consuming wastes and nutrients) to the impaired waters of the Harpeth River watershed are included in the table below. As evident in the table, the City of Franklin discharges the largest volume of wastewater to the Harpeth River.

Table 3. NPDES dischargers of organic loads to impaired waters of the Harpeth River watershed

Permitted facility (NPDES #)	Receiving stream	County	Design flow in Millions of gallons per day (MGD)
Franklin STP (TN0028827)	Harpeth River - RM 85.3	Williamson	12 MGD
Page School (TN0057835)	Harpeth River - RM 101.9	Williamson	0.02 MGD
Best Western-Goose Creek Inn (TN0060216)	Fivemile Creek – RM 1.8	Williamson	0.03 MGD
Oakview Elementary School (TN0067873)	RM 0.6 of unnamed tributary to Fivemile Creek at RM 1.1	Williamson	0.01 MGD
Eagleville HS (TN0057789)	Cheatham Br -RM 1.9	Rutherford	0.016 MGD

In addition to the NPDES dischargers to the system, water withdrawals exist throughout the mainstem of the Harpeth River. The City of Franklin's water intake is located at RM89.2, approximately 100 yards upstream from a low-head dam on the Harpeth River. On average, the City withdraws between two million gallons per day (MGD) and 5 MGD. In addition, there are several pump intake lines in the Harpeth River. During a canoe float conducted by EPA and TDEC in

September 2000 between RM88.1 and 62.4, twenty-one intake lines were observed throughout the Harpeth River. The intake lines were attached to pumps of varying sizes along the riverbank. The vast majority of these pumps were not operating at the time they were observed, and the intake lines attached to these pumps ranged between one and two inches in diameter. However, the specific capacity of each of the observed pumps was not determined.

Available Data

Before any decisions were made concerning how to approach a TMDL for the Harpeth River watershed, an evaluation of available data was conducted. Concerning water quantity data available within the Harpeth River watershed, there are currently five USGS gage stations that measure flow and stage. These stations are described in Table 4 below. Relative to the majority of impaired waters throughout the southeastern United States, the available water quantity dataset is fairly robust.

Table 4. USGS gage stations in the Harpeth River watershed

Station	Location description	Period of record
03432350 Harpeth River at Franklin, TN	State Hwy 96 bridge crossing River Mile 88.1	October 1974 to present
03432390 Spencer Creek near Franklin, TN	U.S. Hwy 31 bridge crossing	Water years 1959 and 1975, April 1999 to present
03432400 Harpeth River below Franklin, TN	0.1 mile below U.S. Hwy 431 River Mile 84.3	August 1988 to present
03433500 Harpeth River at Bellevue, TN	State Hwy 100 bridge crossing River Mile 62.1	April 1920 to present
03434500 Harpeth R near Kingston Springs, TN	U.S. Hwy 70 bridge crossing River Mile 32.4	October 1924 to present

Prior to intensive field survey work conducted on the Harpeth River by EPA and TDEC in 2000 and 2001, the available water quality data in the Harpeth River watershed was mostly limited, and much of it was limited to the Harpeth River in the vicinity of the City of Franklin Sewage Treatment Plant (STP). Most of the data consisted of grab samples taken from the mainstem of the Harpeth River over a period of several years where parameters such as temperature, dissolved oxygen (DO), conductivity, pH, 5-day biochemical oxygen demand (BOD5), and ammonia nitrogen (NH3-N) were measured.

Water quality studies had been conducted on the Harpeth River, but many of these studies had been conducted more than 15 years ago. The State of Tennessee had conducted some of these studies, and the focus of their studies was the segment of the Harpeth River immediately downstream from discharge from the City of Franklin STP. The State's studies generally included the collection of water quality samples such as DO, dissolved oxygen (DO), BOD_5, and NH_3-N. The Environmental and Water Resources Engineering program at Vanderbilt University conducted some water quality studies on the Harpeth River in 1977 (Davis et al, 1977) and 1986 (Sulkin, 1987). In 1977, water quality sampling was conducted including diurnal DO measurements, and hydraulic measurements were made in the Harpeth River from RM85.3 to RM82.0 and RM58.3 to RM54.2. In 1986, hydraulic data was collected and water quality sampling was conducted, including diurnal DO measurements, in the Harpeth River from RM85.3 to RM81.6.

Between 1995 and 1999, TDEC conducted additional water quality studies on the Harpeth River during low-flow periods. In 1995, TDEC collected water quality data concurrent with a time-of-travel study on a 2.5-mile segment of the Harpeth River in the vicinity of a wastewater discharge from the City of Franklin. In 1998 and 1999, TDEC collected diurnal DO data downstream of a 0.2 MGD discharge from the Lynnwood STP. This facility is located at RM 77.9 of the Harpeth River, nearly 1 mile downstream from the downstream boundary of the impaired segment of the Harpeth River.

2000 and 2001 Harpeth River Studies

Data collected prior to 2000 provided a limited understanding concerning the “organic enrichment/DO” impairment of the Harpeth River watershed. Although the available data provided some level of understanding of the DO processes in the Harpeth River immediately downstream from the Franklin STP, a very small amount of data was available in the portion of the watershed located upstream from the City of Franklin’s STP. Based on the available data, it was apparent that low dissolved oxygen levels in the Harpeth River occurred during low-flow conditions. However, the extent and significance of the impairment was not well understood.

In May 2001, EPA made a commitment through a Settlement Agreement associated with a lawsuit that was brought against the Agency, that it would conduct a water quality study of the Harpeth River watershed (Tennessee Environmental Council, et al, 2001). Specifically, EPA agreed to undertake a study of the Harpeth River watershed from the Sneed Road crossing (i.e., RM 66.0 of the Harpeth River) to the headwaters. As a result, the extent of this study needed to include the 303(d)-listed segment of the Harpeth River as well as an unimpaired 12.7-mile segment located immediately downstream from the 303(d)-listed segment. Considering the existence of a USGS gage located at RM62.4, EPA determined it would extend the study down to that point. The purpose of conducting the study was to: 1) characterize water quality conditions and assess pollutant sources contributing to the impairment of the Harpeth River; and 2) analyze contributions of nutrients and oxygen-consuming loads to the Harpeth River watershed as part of the TMDL process.

EPA Region 4 designed and conducted 6 field studies of the Harpeth River, with significant assistance from TDEC, between July 2000 and April 2001. The data and information collected during these studies can be found in EPA’s draft report, “Harpeth River Modeling Data Report: December 2001.” The activities conducted during these studies were as follows:

1. July 28-31, 2000 : reconnaissance (recon) study The purpose of the recon was to gain an understanding of the system sufficient to design an effective low-flow water quality study. An additional objective was added to the scope of the recon when EPA learned of a raw wastewater overflow at the Spencer Creek lift station, near the mouth of Spencer Creek that occurred on July 23. It became important to obtain water quality data on the River before the sewage spill had an impact. Grab samples were collected at stations between RM114.6 and RM62.4 and included the analysis the nitrogen series, total phosphorus, and total organic carbon.
2. August 21-26, 2000 : low-flow study The study focused on the oxygen producing and consuming processes in the Harpeth River and its primary tributaries (Little Harpeth River, West Harpeth River, and Spencer Creek). Measurements were made of stream reaeration rate coefficients downstream from the Franklin STP and the Lynnwood STP. Sediment Oxygen Demand (SOD) measurements were made at stations amenable to in-situ chamber measurements. Water column production and respiration measurements were made along the length of the stream using light and dark bottle technology. Diurnal water quality measurements were made simultaneously at thirteen stations using multi-probe "sonde" instrumentation at half hour intervals over a span of more than thirty consecutive hours. Water quality samples were taken from the Franklin STP, the Lynnwood STP, the mainstem of the River, and the primary tributaries to the River. Meteorological measurements were made during the study including rainfall, wind speed, and wind direction. In addition, cross-section surveys were made at 22 stations along the mainstem of the Harpeth River.
3. August 27-28, 2000 : rainfall runoff study A two-day loading survey was conducted at three USGS gage stations located on the Harpeth River and one USGS gage station located on Spencer Creek. Three water quality samples were collected from each of these stations during the rising and falling limbs of the individual hydrographs.
4. September 20-24, 2000 : follow-up low-flow survey During a follow-up survey, additional time-of travel data was collected in areas upstream and downstream of the segment where the reaeration study had been conducted in August. A source assessment was also conducted in the Spencer Creek watershed. In addition, a longitudinal float survey was conducted from RM88.1 to RM62.4 and withdrawal lines connected to pumps along the river were documented.
5. September 25-28, 2000 : rainfall runoff study A two-day loading survey was conducted at three USGS gage stations located on the Harpeth River and one USGS gage station located on Spencer Creek. Three water quality samples were collected from each of these stations during the rising and falling limbs of the individual hydrographs.

6. April 16-20, 2001 : medium-flow study The study focused on the oxygen producing and consuming processes in the Harpeth River and its primary tributaries (Little Harpeth River, West Harpeth River, and Spencer Creek) during approximately average environmental conditions (i.e., the flows and temperatures during the springtime were anticipated to be close to the annual average values). It was assumed that these conditions would also reflect the combined impact of point sources and nonpoint sources. Measurements were made of diffusion, which could be correlated to reaeration rate coefficients. Water column production and respiration measurements were made along the length of the stream using light and dark bottle technology. Diurnal water quality measurements were made simultaneously at sixteen stations using multi-probe “sonde” instrumentation at half hour intervals over a span of more than thirty consecutive hours. Water quality samples were taken from the Franklin STP, the Lynnwood STP, the Cartwright Creek Utility District STP (discharges to RM68.8), the mainstem of the River, and 12 tributaries to the Harpeth River. In addition, meteorological measurements were made during the study including rainfall, wind speed, and wind direction.

Assessment of Water Quality and Pollution Sources

A significant amount of information was learned from the Harpeth River dataset collected in 2000 and 2001. Observations in the field as well as assessments of the data collected contributed to the decisions relating to the development of the models described later in this report. The important field observations and aspects of the water quality and pollution source assessments are described as follows:

- The Harpeth River appears to be a gaining-losing stream (i.e., there is significant interflow between the river and groundwater), at least in one area of the watershed during low flow conditions. During the July 2000 reconnaissance, a 150-meter segment of the Harpeth River channel, located immediately downstream from the low-head dam at RM89.2, was observed to be completely dry. However, there were no other observed hydraulic discontinuities in the system.

- As mentioned in the “Dischargers and Withdrawals” section of this report, at least 21 pumps potentially withdraw water from the Harpeth River between RM88.1 and RM62.4. Considering the apparent sizes of the pumps, they would probably not have any significant impact on the flow in the river unless the majority of them were operating simultaneously during low-flow conditions. It is believed that the vast majority of these pumps were not operating during the periods when the low-flow studies were conducted and therefore dd not have any significant impact on flow, travel time, or water quality.

- The algae that exists in the Harpeth River appears to be dominated by periphyton. There is no significant presence of macrophytes in the

Harpeth River, and the chlorophyll a and nutrient levels measured in the water column were very low (Table 5). However, the magnitudes of the diurnal swings in DO were indicative of significant algal productivity and respiration (Figure 4 and Figure 5).

- As indicated by algal growth potential tests conducted during the August 2000 study, the Harpeth River appears to be predominantly a nitrogen-limited system during low flows. As indicated by the April 2000 study, however, the limiting nutrient varies from station to station during higher flow conditions.
- The City of Franklin STP discharges a significant amount of nutrient loads and BOD loads to the Harpeth River. In terms of effluent concentration, however, the nitrogen and BOD levels in the treated wastewater are considerably low (Table 5 and Table 6).
- During the August 2000 study in the vicinity of RM114.6, a dead calf was observed in the river. (The sampling at this station was conducted upstream from any influence that the dead calf may have had on water quality.) Although this is certainly not something that EPA or TDEC would attempt to simulate in a model, it is recognized that this may be an indicator that the agricultural best management practices in the headwaters of the Harpeth River watershed need improvement.
- During the August 2000 study, the lowest levels of DO in throughout the watershed were observed in the headwaters (i.e., RM114.6) as demonstrated in Figure 4. The average DO values generally increased in the downstream direction. In addition, the highest BOD concentrations in the system during the August 2000 study (Table 5) as well as the April 2001 study (Table 6) were also observed at RM114.6.
- The DO levels in the mainstem of the Harpeth River during the April 2001 study were all above 8.0 mg/l. It is likely that the DO levels in the system are only problematic during low-flow and high temperature conditions.
- Some of the measured DO levels in the Harpeth River at RM62.4 (downstream from the §303(d)-listed segment) were below TDEC's water quality standard for dissolved oxygen of 5.0 mg/l. Therefore, EPA and TDEC decided to extend the model down to RM32.4 (the location of a downstream USGS gage station).
- Based on the available data, the primary sources of BOD in the watershed appear to be: 1) the City of Franklin STP; and 2) agricultural areas in the headwaters. Based on the available data, the sources of nutrient loads appear to be fairly well distributed throughout the watershed.
- Use of a hydrodynamic model upstream from RM88.1 is not practical. The observed low flows in the upper Harpeth River watershed

(frequently below 1.0 cubic feet per second) combined with the observed slow travel times result in a significant stability issue with regard to hydrodynamic modeling.

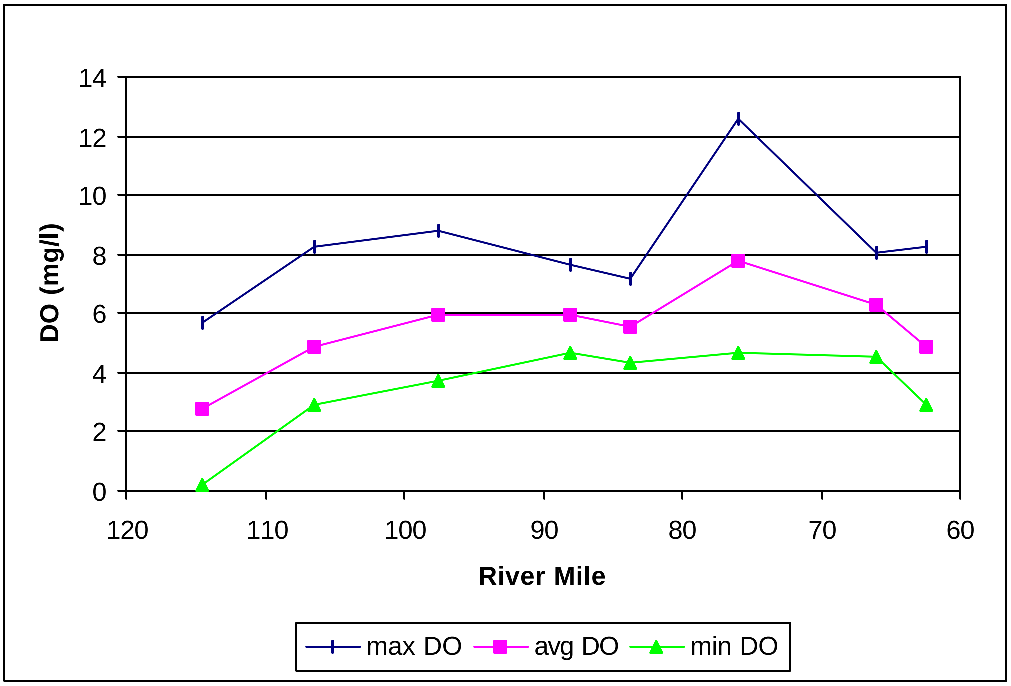


Figure 4. Longitudinal DO profile during the August 2000 study

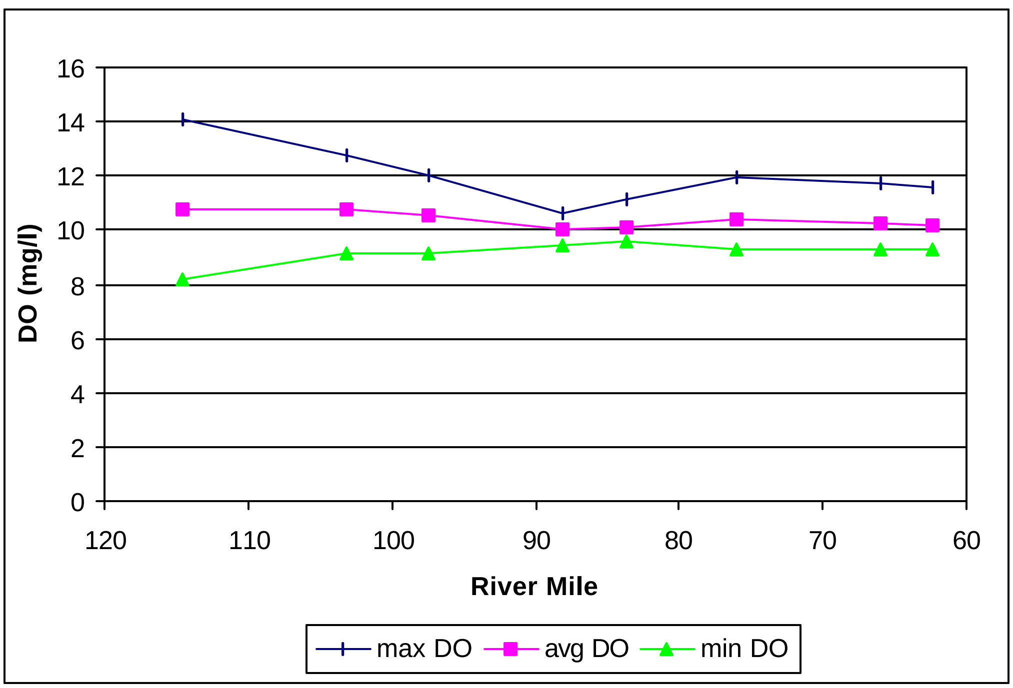


Figure 5. Longitudinal DO profile during the April 2001 study

Table 5. Water quality data collected in August 2000

Station	Flow (cfs)	Ultimate CBOD (mg/l)	NH_3-N (mg/l)	NO_2/NO_3 (mg/l)	TKN (mg/l)	Total N (mg/l)	Total P (mg/l)	Chl a (ug/l)
RM114.6	0.02	7.13	0.06	0.05	0.84	0.89	0.09	5
RM106.5	0.03	5.61	0.08	0.19	0.64	0.83	0.25	-
RM97.5	0.03	3.56	0.03	0.05	0.54	0.59	0.26	-
RM88.1	2.6	0.98	0.09	0.29	0.42	0.71	0.28	0.64
Spencer C	1.9	2.72	0.05	0.29	0.47	0.76	0.36	2.75
RM84.4	9.0	3.78	0.09	1.20	0.70	0.77	1.30	1.28
W. Harp R	0.5	2.36	0.07	0.05	0.24	0.29	0.24	2
RM76.0	12.8	3.5	0.04	0.57	0.37	0.94	0.67	2.6
RM66.0	10.9	3.62	0.06	0.36	0.48	0.84	0.43	-
L. Harp R	0.03	1.73	0.05	0.13	0.50	0.63	0.31	6.4
RM62.4	12.0	1.78	0.07	0.31	0.39	0.70	0.46	3.8
Franklin STP	4.96	5.53	0.06	1.90	1.0	2.90	1.8	-
Lynnwood STP	0.24	16.96	0.11	10.0	1.4	11.4	4.0	-

Table 6. Water quality data collected in August 2001

Station	Flow (cfs)	Ultimate CBOD (mg/l)	NH_3-N (mg/l)	NO_2/NO_3 (mg/l)	TKN (mg/l)	Total N (mg/l)	Total P (mg/l)	Chl a (ug/l)
RM114.6	24.4	5.25	< 0.05	0.71	0.25	0.96	0.06	0.47
Arrington C	17.5	2.15	< 0.05	0.65	0.15	0.80	0.30	1.43
RM103.1	109	2.64	< 0.05	0.64	0.21	0.85	0.19	0.96
Starnes Cr	5.7	4.46	< 0.05	0.76	0.21	0.97	0.28	0.90
RM97.5	139	4.92	< 0.05	0.70	0.18	0.88	0.20	0.7
5mile Cr	10.4	2.75	< 0.05	1.30	0.2	1.50	0.40	1.73
Watson Br	4.9	3.81	< 0.05	0.79	0.225	1.01	0.34	2.06
RM88.1	178	4.08	< 0.05	0.83	0.23	1.06	0.25	1.48
Spencer C	7.2	3.93	< 0.05	1.10	0.20	1.30	0.27	2.37
RM84.4	213	3.43	< 0.05	1.00	0.24	1.24	0.29	1.28
W. Harp R	130	2.26	< 0.05	0.88	0.15	1.03	0.18	1.26
RM76.0	369	3.04	< 0.05	0.99	0.25	1.24	0.25	0.89
L. Harp R	39.3	3.31	< 0.05	1.20	0.16	1.36	0.22	0.78
RM62.4	503	2.84	< 0.05	0.95	0.27	1.22	0.26	1.24
Franklin STP	6.18	11.94	< 0.05	2.70	0.94	3.64	0.70	-
Lynnwood STP	0.21	13.07	0.051	4.50	0.83	5.33	1.1	-
Cartwright Cr STP	0.52	8.2	< 0.05	9.20	0.67	9.87	1.5	-

Modeling Approach

Although the low DO levels in the Harpeth River are understood to occur during low-flow conditions, significant pollutant loads can be washed into the river during wet weather events. Pollutant loads washed into the river during wet weather events impact algal growth, which in turn affects DO levels. EPA and TDEC determined that using a dynamic model would allow the assessment of instream water quality processes during any combination of low-flow, medium flow, and high flow events. Considering the historical flow and stage record available for the Harpeth River as well as meteorological stations in the proximity of the Harpeth River watershed, enough information was available to develop and calibrate a hydrologic model for the Harpeth River watershed and a hydrodynamic model of the Harpeth River from RM88.1 to RM32.4. Although the available water quality data was limited beyond the 2000 and 2001 studies, EPA and TDEC determined the dataset was sufficient to parameterize the loading characteristics of a watershed model and the eutrophication/dissolved oxygen processes of an instream water quality model that could be linked to the hydrodynamic model.

EPA and TDEC are also challenged with the current lack of water quality data available downstream from RM62.4. Although a TMDL is not required for the segment of the Harpeth River downstream from RM62.4 (i.e., it is not included on the §303(d) list), EPA and TDEC believe it will be useful to have a model parameterized down to RM32.4. Although a calibration of this segment is not possible without additional water quality data, the model can be used as a tool to target locations for data collection efforts in the future. In addition, the parameters used in the model upstream from this segment can be extrapolated to this segment to approximate water quality impacts resulting from upstream sources.

The system of the dynamic models consists of the watershed model LSPC, the hydrodynamic model CE-QUAL-RIV1, and the eutrophication/DO model WASP, version 6.0. These models are linked and are developed to simulate hydrologic, hydrodynamic, and water quality processes in the watershed for water year 1992 through 2001 (i.e., WY92 – WY01 or October 1991 through September 2001). This 10-year period includes the periods for which data was available to parameterize and calibrate these models.

Concerning the upper Harpeth River (i.e., above RM88.1) and the impaired waters that drain to the upper Harpeth River, as stated earlier in this report the development of a dynamic model was not practical. In addition, the extremely low-flows and sluggish travel times in the upper Harpeth River would present problems concerning the application of a steady-state riverine model. However, EPA made a commitment through a Settlement Agreement to develop a water quality model of all of the impaired waters of the watershed, including the upper Harpeth River. Therefore, EPA and TDEC determined that the most appropriate modeling tool that could be applied to the upper Harpeth River would be a steady-state dissolved oxygen model. Although there would be significant limitations of such a model, it could be used as a tool to develop wasteload allocations and load allocations. The steady-state model, QUAL2E, was selected to try to simulate the upstream water quality processes during low-flow conditions.

LSPC Modeling Effort

The Loading Simulation Program in C++ (LSPC) is a comprehensive data management and modeling system that is capable of representing loading, both flow and water quality, from non-point and point sources and simulating in-stream processes. LSPC was used to generate tributary and watershed flows and biochemical oxygen demand, nitrogen and phosphorus loads for the Harpeth River watershed. The fows were then used as boundary and lateral inputs for the CE-QUAL-RIV1 hydrodynamic model and the WASP water quality model applications to the Harpeth River. LSPC includes Hydrological Simulation Program – Fortran (HSPF) algorithms for hydrology, sediment, general water quality, and stream transport.

To simulate stream flows, watershed loadings and resulting concentrations of nutrients and BOD in the streams, the Harpeth River Basin was divided into subbasins according to USGS stream gage locations, USGS 30 meter Digital Elevation Model (DEM) data, and USGS level 3 (RF3) stream data. These subbasins are shown in Figure 6. Each subbasin was divided according to landuse from the Multi-Resolution Land Characteristics Consortium (MRLC), National Land Cover Data (NLCD) (see Figure 7 and Table 7). This landuse data is based on early 1990's Landsat satellite images. The LSPC model contains a database of hydrologic, sediment and water quality parameter values. These values were used in the initial parameterization of the model and then the parameter values were adjusted in model calibration. Precipitation and air temperature data from one of five National Climatic Data Center (NCDC) stations was input to each subbasin. Additionally, potential evapotranspiration was estimated according to the Hamon method in the Better Assessment Science Integrating point and Nonpoint Sources (BASINS) WDMUtil program and used as input to the LSPC model (Hummel et al, 2001).

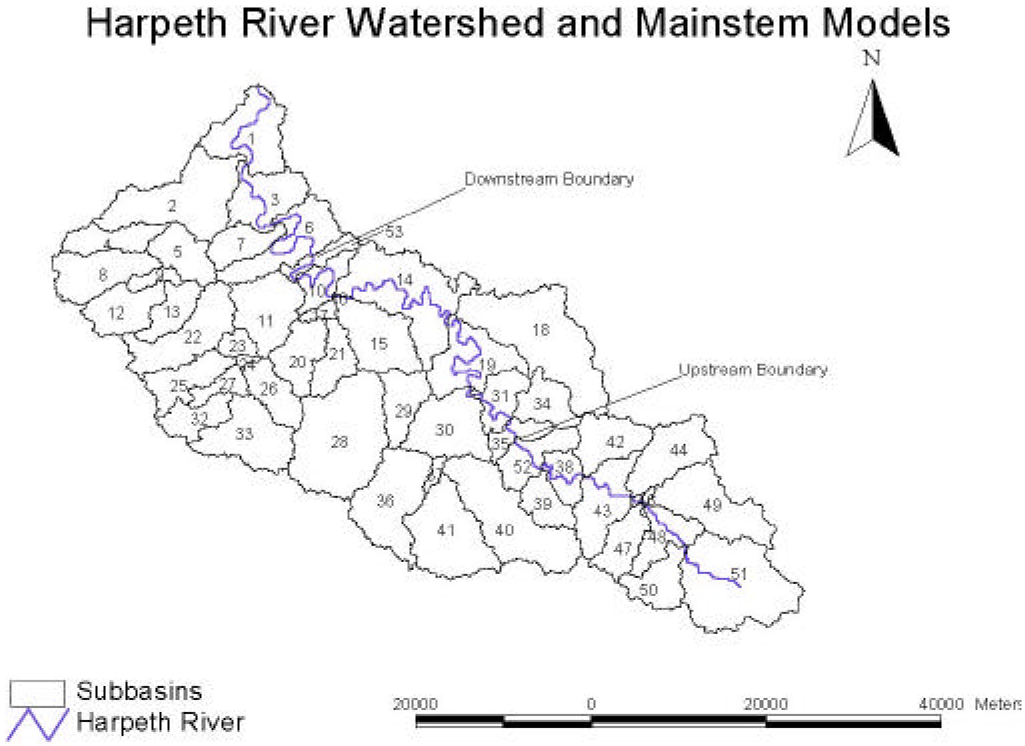


Figure 6. Watershed delineation for the LSPC model

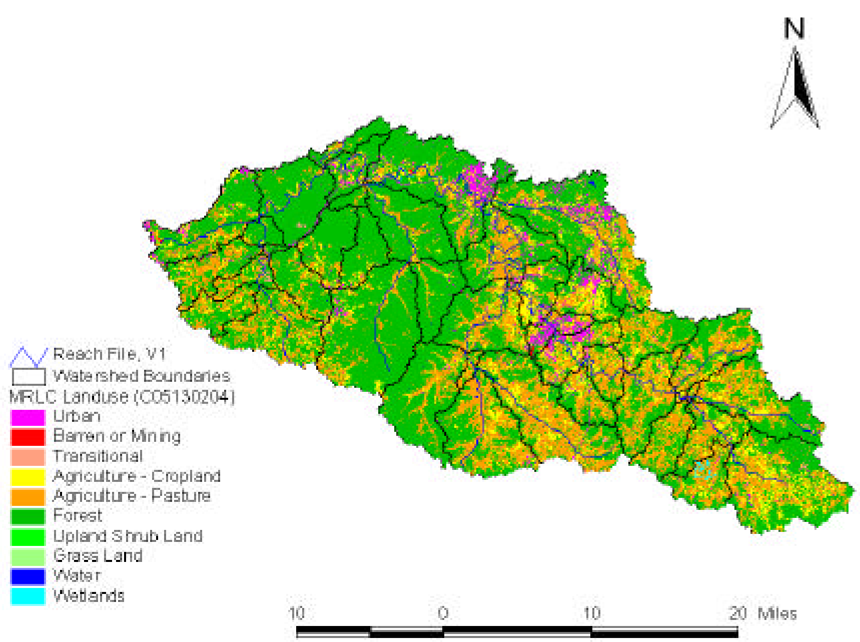


Figure 7. Landuse distribution in the Harpeth River watershed

Table 7. Percentages of landuse types in the Harpeth River watershed

Subbasin	Open Water	Low Intensity Residential	High Intensity Residential	High Intensity Commercial/Industrial/Transportation	Quarries/Strip Mines/Gravel Pits	Transitional	Deciduous Forest	Evergreen Forest	Mixed Forest	Pasture/Hay	Row Crops	Other Grasses (Urban/recreational; e.g. parks, lawns, golf courses)	Woody Wetlands	Emergent Herbaceous Wetlands	Totals	
	2192	10342	1210	5070	325	1031	277693	14014	54862	130366	49055	8209	756	13	555137	acres
	3	16	2	8	1	2	434	22	86	204	77	13	1	0	867	sq miles
	0.4%	1.9%	0.2%	0.9%	0.1%	0.2%	50.0%	2.5%	9.9%	23.5%	8.8%	1.5%	0.1%	0.0%		

The hydrology of the LSPC model was calibrated for water years 1992 through 2001 at USGS gages 03434500, 03433500, 03432350, which are respectively located at RM32.4, RM62.4, RM84.4, and RM88.1 of the Harpeth River. The calibrations for each of these gages are shown in Figure 8 through Figure 19 and Table 8 through Table 13.

Table 8. Water Year 1992 Flow Calibration Statistics at USGS gage 3432350, up-stream

Simulation Name:	Harpeth River at 3432350	**Simulation Period:**	
		Watershed Area (ac):	122,240
Selected a Year for Flow Analysis:	**1992**		
Type of Year (1=Calendar, 2=Water Year)	**2**	**Baseflow PERCENTILE:**	2.5
Water Year 1992:		*Usually 1%-5%*	
10/1/1991 to 9/30/1992			
Total Simulated In-stream Flow:	**19.97**	Total Observed In-stream Flow:	**19.06**
Total of highest 10% flows:	**11.96**	Total of Observed highest 10% flows:	**11.26**
Total of lowest 50% flows:	**1.36**	Total of Observed Lowest 50% flows:	**1.20**
Simulated Summer Flow Volume (months 7-9):	**3.40**	Observed Summer Flow Volume (7-9):	**1.90**
Simulated Fall Flow Volume (months 10-12):	**7.06**	Observed Fall Flow Volume (10-12):	**7.08**
Simulated Winter Flow Volume (months 1-3):	**7.55**	Observed Winter Flow Volume (1-3):	**8.06**
Simulated Spring Flow Volume (months 4-6):	**1.96**	Observed Spring Flow Volume (4-6):	**2.03**
Total Simulated Storm Volume:	**19.24**	Total Observed Storm Volume:	**18.69**
Simulated Summer Storm Volume (7-9):	**3.22**	Observed Summer Storm Volume (7-9):	**1.80**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**4.56**	10	
Error in 50% lowest flows:	**11.63**	10	
Error in 10% highest flows:	**5.90**	15	
Seasonal volume error - Summer:	**44.27**	30	
Seasonal volume error - Fall:	**-0.21**	30	
Seasonal volume error - Winter:	**-6.72**	30	
Seasonal volume error - Spring:	**-3.67**	30	
Error in storm volumes:	**2.85**	20	
Error in summer storm volumes:	**43.94**	50	

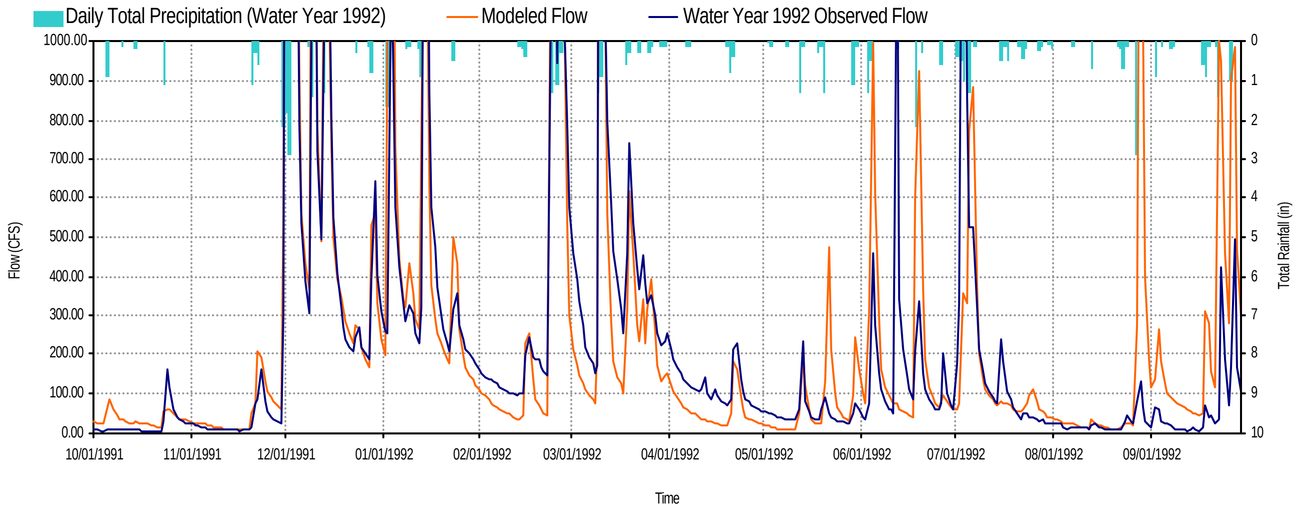


Figure 8. Water Year 1992 Flow Calibration Timeseries Chart at USGS gage 3432350, up-stream

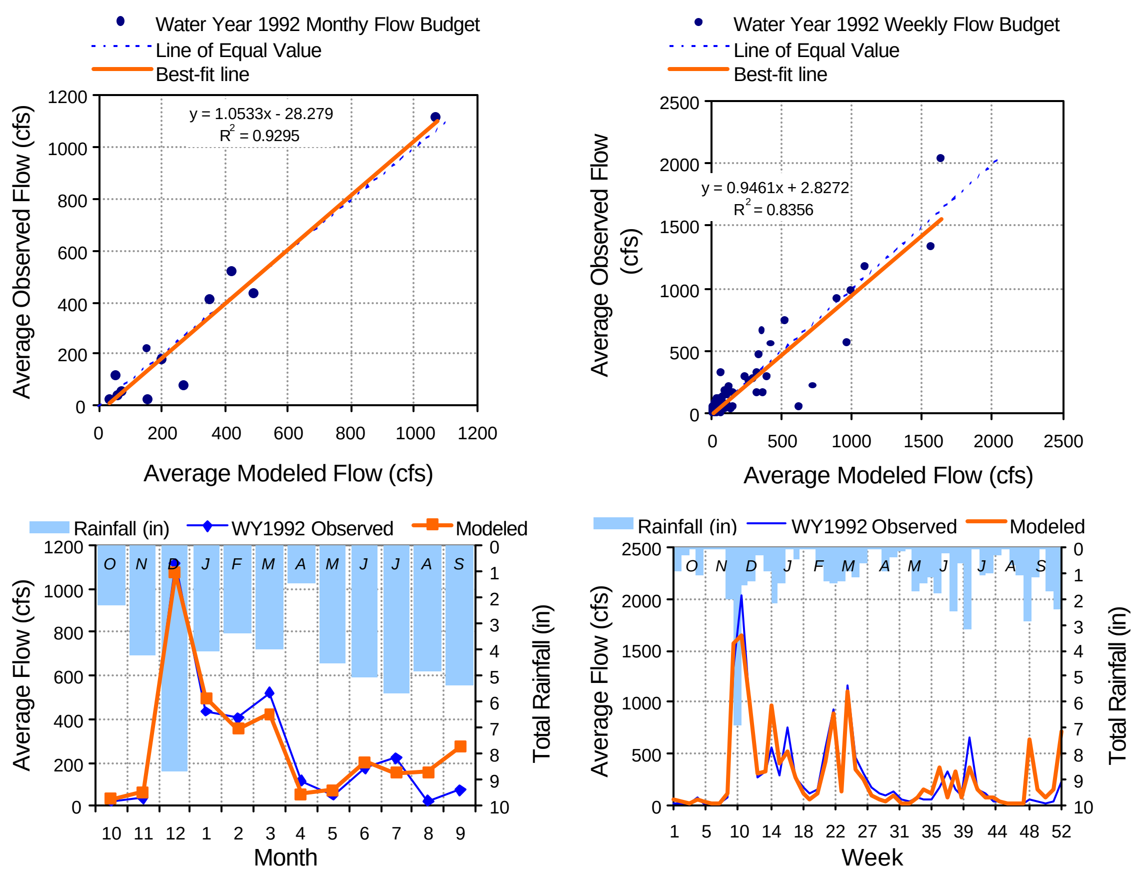


Figure 9. Water Year 1992 Flow Calibration Summary Charts at USGS gage 3432350, up-stream

Table 9. Water Year 2001 Flow Calibration Statistics at USGS gage 3432350, up-stream

Simulation Name:	Harpeth River at 3432350	**Simulation Period:**	
		Watershed Area (ac):	122,240
Selected a Year for Flow Analysis:	**2001**		
Type of Year (1=Calendar, 2=Water Year)	**2**	**Baseflow PERCENTILE:**	2.5
Water Year 2001:		*Usually 1%-5%*	
10/1/2000 to 9/30/2001			
Total Simulated In-stream Flow:	**16.92**	Total Observed In-stream Flow:	**15.67**
Total of highest 10% flows:	**9.96**	Total of Observed highest 10% flows:	**10.38**
Total of lowest 50% flows:	**1.30**	Total of Observed Lowest 50% flows:	**0.72**
Simulated Summer Flow Volume (months 7-9):	**2.08**	Observed Summer Flow Volume (7-9):	**0.78**
Simulated Fall Flow Volume (months 10-12):	**2.77**	Observed Fall Flow Volume (10-12):	**3.11**
Simulated Winter Flow Volume (months 1-3):	**10.37**	Observed Winter Flow Volume (1-3):	**10.28**
Simulated Spring Flow Volume (months 4-6):	**1.71**	Observed Spring Flow Volume (4-6):	**1.49**
Total Simulated Storm Volume:	**16.69**	Total Observed Storm Volume:	**15.51**
Simulated Summer Storm Volume (7-9):	**2.02**	Observed Summer Storm Volume (7-9):	**0.74**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**7.39**	10	
Error in 50% lowest flows:	**44.54**	10	
Error in 10% highest flows:	**-4.24**	15	
Seasonal volume error - Summer:	**62.35**	30	
Seasonal volume error - Fall:	**-12.62**	30	
Seasonal volume error - Winter:	**0.81**	30	
Seasonal volume error - Spring:	**12.86**	30	
Error in storm volumes:	**7.08**	20	
Error in summer storm volumes:	**63.22**	50	

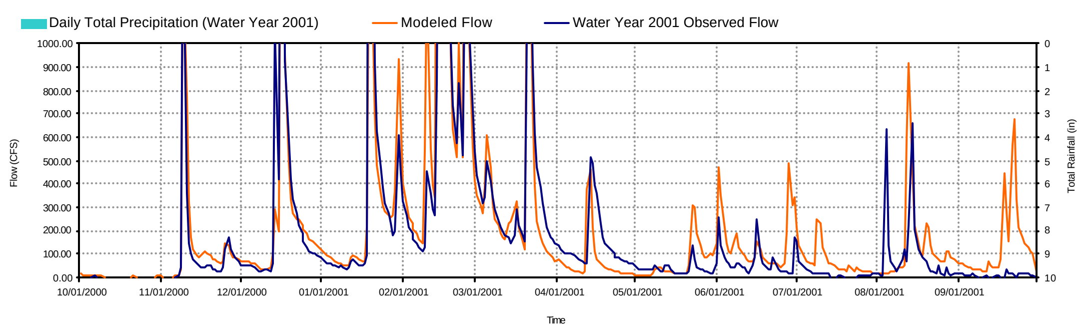


Figure 10. Water Year 2001 Flow Calibration Timeseries Chart at USGS gage 3432350, up-stream

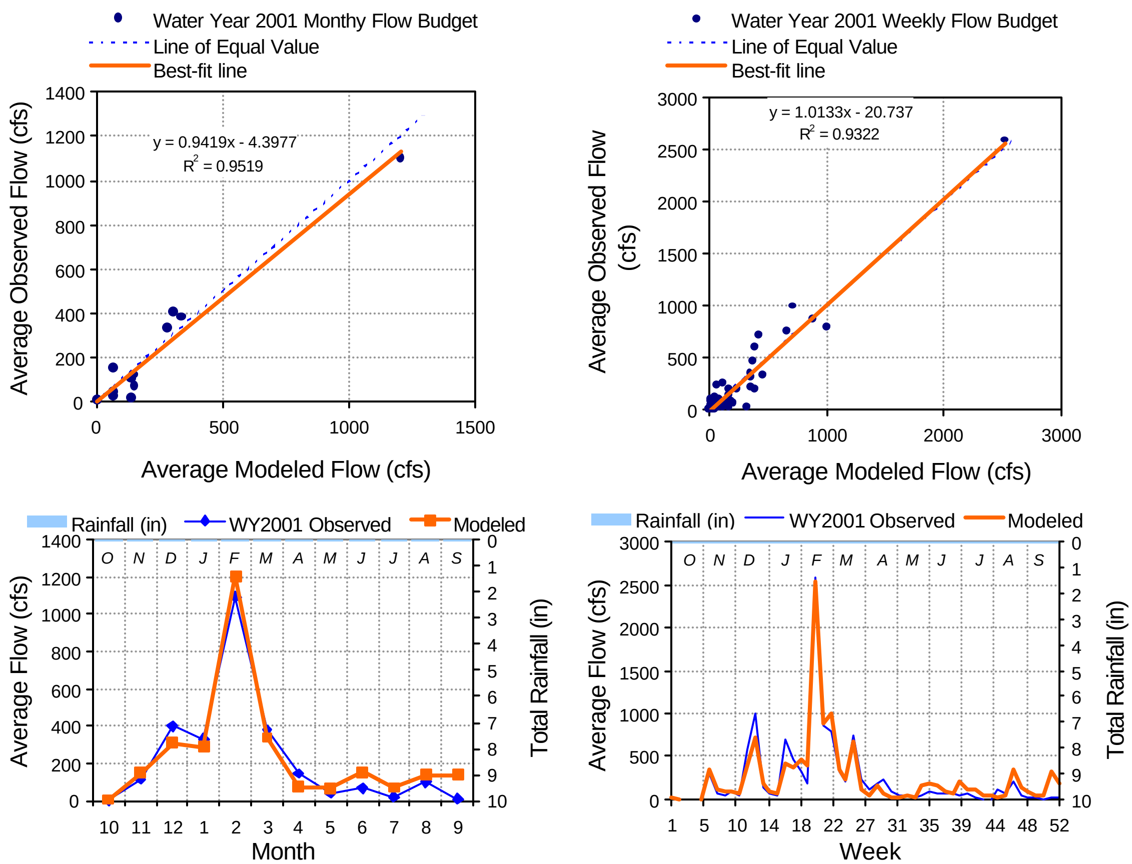


Figure 11. Water Year 2001 Flow Calibration Summary Charts at USGS gage 3432350, up-stream

Table 10. Water Year 1992 Flow Calibration Statistics at USGS gage 3433500, mid-stream

Simulation Name:	Harpeth River at USGS gage 3433500	**Simulation Period:**	
		Watershed Area (ac):	261,120
Selected a Year for Flow Analysis:	**1992**		
Type of Year (1=Calendar, 2=Water Year)	**2**	**Baseflow PERCENTILE:**	2.5
Water Year 1992:		*Usually 1%-5%*	
10/1/1991 to 9/30/1992			
Total Simulated In-stream Flow:	**19.71**	Total Observed In-stream Flow:	**20.56**
Total of highest 10% flows:	**11.14**	Total of Observed highest 10% flows:	**11.34**
Total of lowest 50% flows:	**1.60**	Total of Observed Lowest 50% flows:	**1.78**
Simulated Summer Flow Volume (months 7-9):	**2.51**	Observed Summer Flow Volume (7-9):	**2.41**
Simulated Fall Flow Volume (months 10-12):	**7.84**	Observed Fall Flow Volume (10-12):	**6.80**
Simulated Winter Flow Volume (months 1-3):	**7.38**	Observed Winter Flow Volume (1-3):	**8.56**
Simulated Spring Flow Volume (months 4-6):	**1.98**	Observed Spring Flow Volume (4-6):	**2.79**
Total Simulated Storm Volume:	**18.93**	Total Observed Storm Volume:	**20.06**
Simulated Summer Storm Volume (7-9):	**2.32**	Observed Summer Storm Volume (7-9):	**2.28**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-4.30**	10	
Error in 50% lowest flows:	**-11.22**	10	
Error in 10% highest flows:	**-1.77**	15	
Seasonal volume error - Summer:	**4.27**	30	
Seasonal volume error - Fall:	**13.29**	30	
Seasonal volume error - Winter:	**-16.00**	30	
Seasonal volume error - Spring:	**-41.31**	30	
Error in storm volumes:	**-5.96**	20	
Error in summer storm volumes:	**1.68**	50	

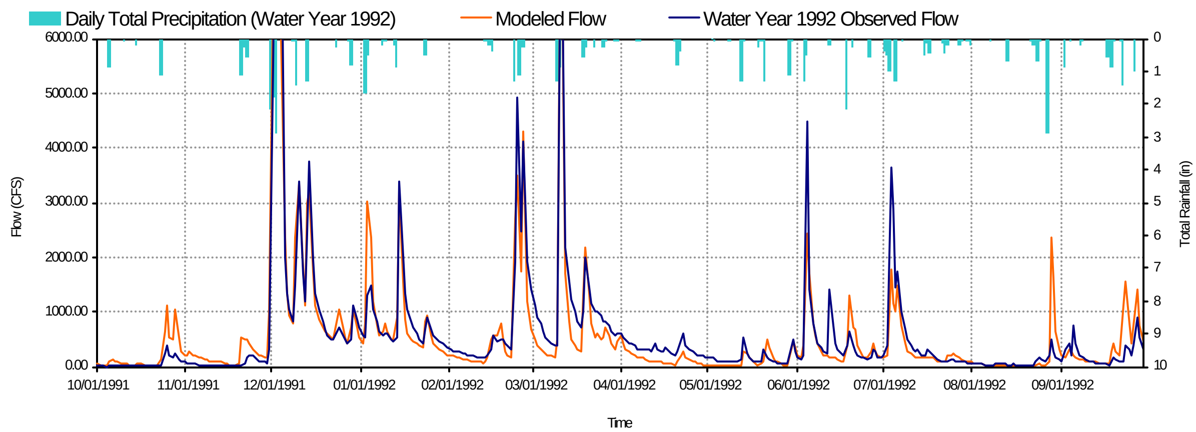


Figure 12. Water Year 1992 Flow Calibration Timeseries Chart at USGS gage 3433500, mid-stream

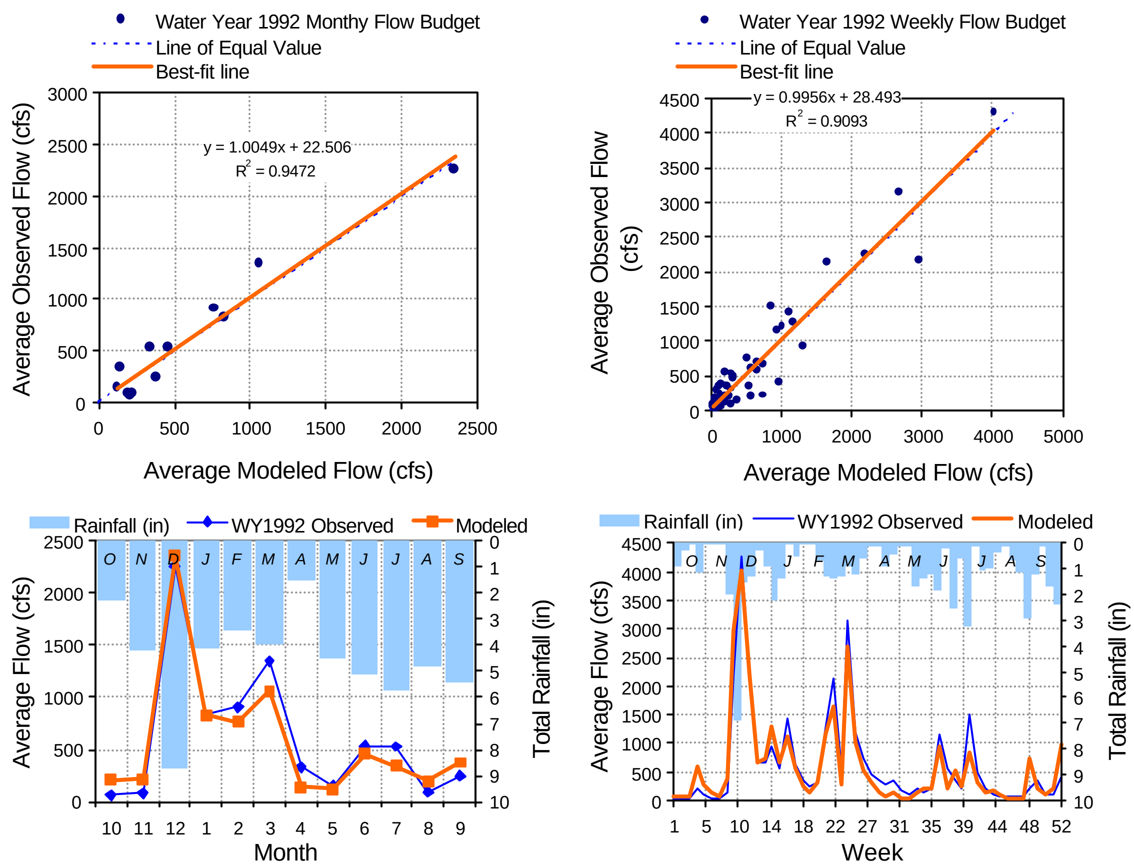


Figure 13. Water Year 1992 Flow Calibration Summary Charts at USGS gage 3433500, mid-stream

Table 11. Water Year 2001 Flow Calibration Statistics at USGS gage 3433500, mid-stream

Simulation Name:	Harpeth River at USGS gage 3433500	**Simulation Period:**	
		Watershed Area (ac):	261,120
Selected a Year for Flow Analysis:	**2001**		
Type of Year (1=Calendar, 2=Water Year)	**2**	**Baseflow PERCENTILE:**	2.5
Water Year 2001:		*Usually 1%-5%*	
10/1/2000 to 9/30/2001			
Total Simulated In-stream Flow:	**16.07**	Total Observed In-stream Flow:	**16.09**
Total of highest 10% flows:	**9.51**	Total of Observed highest 10% flows:	**9.75**
Total of lowest 50% flows:	**1.29**	Total of Observed Lowest 50% flows:	**1.15**
Simulated Summer Flow Volume (months 7-9):	**1.48**	Observed Summer Flow Volume (7-9):	**0.83**
Simulated Fall Flow Volume (months 10-12):	**3.10**	Observed Fall Flow Volume (10-12):	**2.85**
Simulated Winter Flow Volume (months 1-3):	**9.76**	Observed Winter Flow Volume (1-3):	**10.30**
Simulated Spring Flow Volume (months 4-6):	**1.74**	Observed Spring Flow Volume (4-6):	**2.11**
Total Simulated Storm Volume:	**15.86**	Total Observed Storm Volume:	**15.64**
Simulated Summer Storm Volume (7-9):	**1.43**	Observed Summer Storm Volume (7-9):	**0.72**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-0.18**	10	
Error in 50% lowest flows:	**11.22**	10	
Error in 10% highest flows:	**-2.54**	15	
Seasonal volume error - Summer:	**43.76**	30	
Seasonal volume error - Fall:	**7.95**	30	
Seasonal volume error - Winter:	**-5.60**	30	
Seasonal volume error - Spring:	**-21.66**	30	
Error in storm volumes:	**1.41**	20	
Error in summer storm volumes:	**49.81**	50	

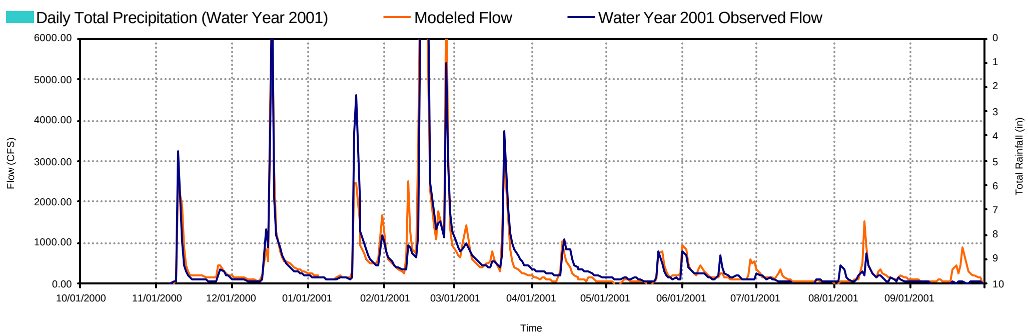


Figure 14. Water Year 2001 Flow Calibration Timeseries Chart at USGS gage 3433500, mid-stream

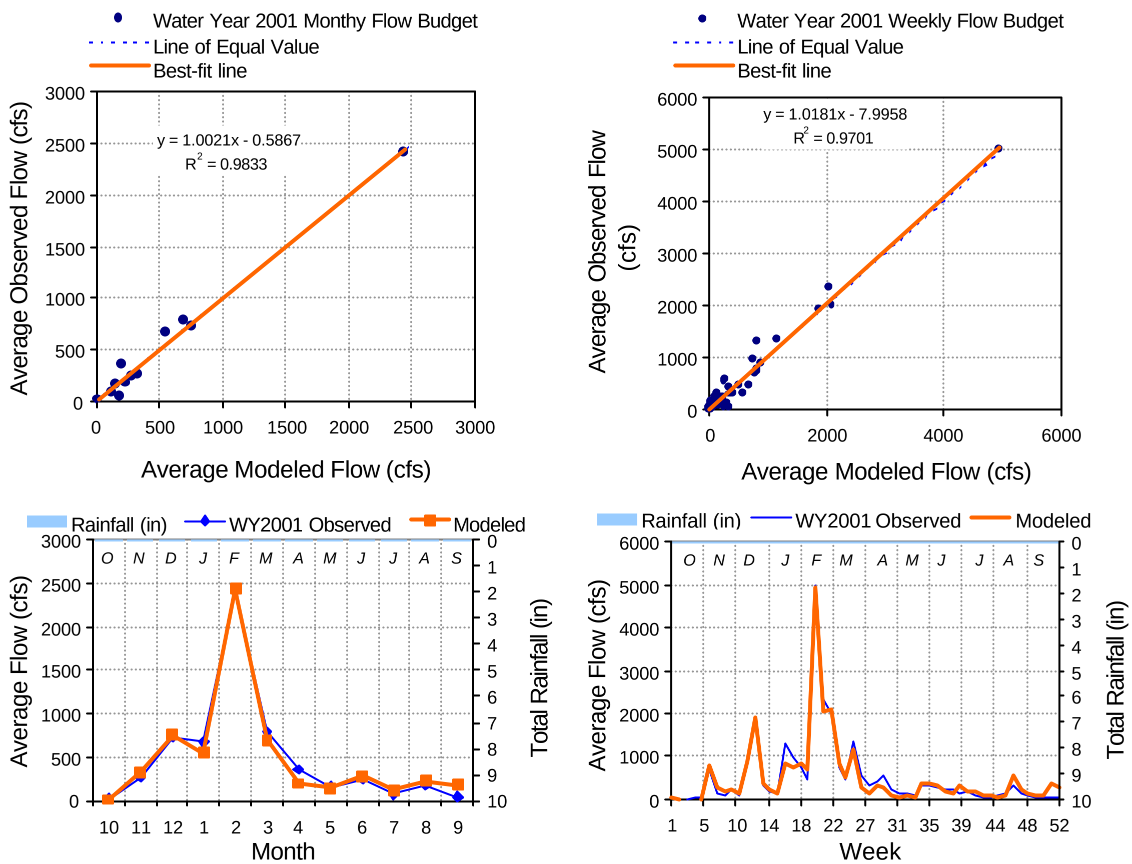


Figure 15. Water Year 2001 Flow Calibration Summary Charts at USGS gage 3433500, mid-stream

Table 12. Water Year 1992 Flow Calibration Statistics at USGS gage 3434500, down-stream

Simulation Name:	Harpeth River at USGS gage 3434500	**Simulation Period:**	
		Watershed Area (ac):	435840.00
Selected a Year for Flow Analysis:	**1992**		
~~Type of Year (1=Calendar, 2=Water Year)~~	**2**	**Baseflow PERCENTILE:**	2.5
Water Year 1992:		*Usually 1%-5%*	
10/1/1991 to 9/30/1992			
Total Simulated In-stream Flow:	**20.77**	Total Observed In-stream Flow:	**18.74**
Total of highest 10% flows:	**11.56**	Total of Observed highest 10% flows:	**9.26**
Total of lowest 50% flows:	**1.70**	Total of Observed Lowest 50% flows:	**2.29**
Simulated Summer Flow Volume (months 7-9):	**2.30**	Observed Summer Flow Volume (7-9):	**2.17**
Simulated Fall Flow Volume (months 10-12):	**8.84**	Observed Fall Flow Volume (10-12):	**6.00**
Simulated Winter Flow Volume (months 1-3):	**7.81**	Observed Winter Flow Volume (1-3):	**7.60**
Simulated Spring Flow Volume (months 4-6):	**1.82**	Observed Spring Flow Volume (4-6):	**2.97**
Total Simulated Storm Volume:	**19.89**	Total Observed Storm Volume:	**17.10**
Simulated Summer Storm Volume (7-9):	**2.08**	Observed Summer Storm Volume (7-9):	**1.76**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**9.79**	10	
Error in 50% lowest flows:	**-34.78**	10	
Error in 10% highest flows:	**19.93**	15	
Seasonal volume error - Summer:	**5.43**	30	
Seasonal volume error - Fall:	**32.14**	30	
Seasonal volume error - Winter:	**2.67**	30	
Seasonal volume error - Spring:	**-62.59**	30	
Error in storm volumes:	**14.03**	20	
Error in summer storm volumes:	**15.12**	50	

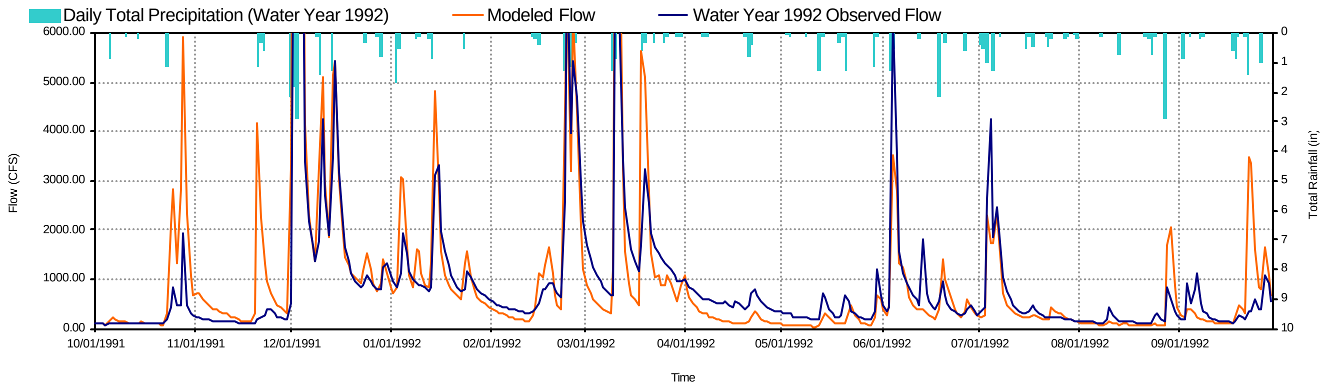


Figure 16. Water Year 1992 Flow Calibration Timeseries Chart at USGS gage 3434500, down-stream

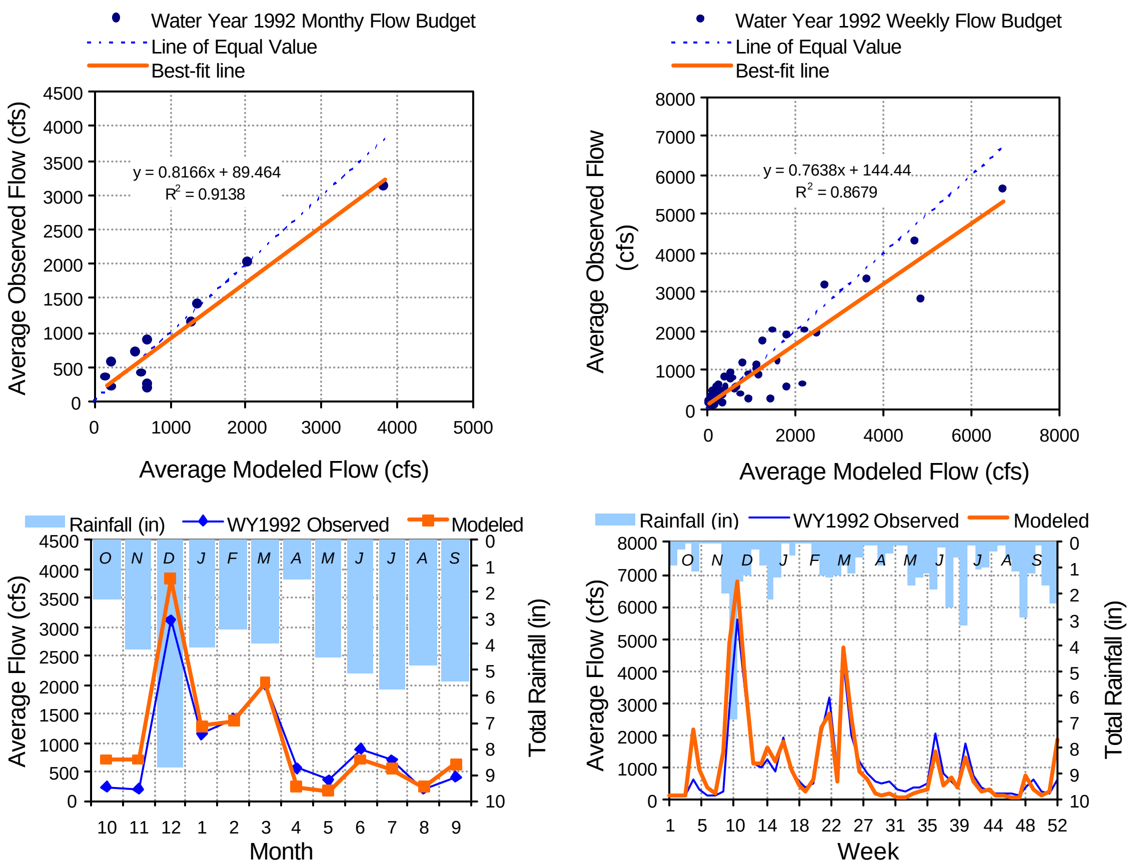


Figure 17. Water Year 1992 Flow Calibration Summary Charts at USGS gage 3434500, down-stream

Table 13. Water Year 2001 Flow Calibration Statistics at USGS gage 3434500, down-stream

Simulation Name:	Harpeth River at USGS gage 3434500	**Simulation Period:**	
		Watershed Area (ac):	435840.00
Selected a Year for Flow Analysis:	**2001**		
Type of Year (1=Calendar, 2=Water Year)	**2**	**Baseflow PERCENTILE:**	2.5
Water Year 2001:		*Usually 1%-5%*	
10/1/2000 to 9/30/2001			
Total Simulated In-stream Flow:	**14.24**	Total Observed In-stream Flow:	**14.84**
Total of highest 10% flows:	**8.52**	Total of Observed highest 10% flows:	**8.42**
Total of lowest 50% flows:	**1.13**	Total of Observed Lowest 50% flows:	**1.30**
Simulated Summer Flow Volume (months 7-9):	**1.04**	Observed Summer Flow Volume (7-9):	**0.74**
Simulated Fall Flow Volume (months 10-12):	**2.50**	Observed Fall Flow Volume (10-12):	**2.63**
Simulated Winter Flow Volume (months 1-3):	**9.14**	Observed Winter Flow Volume (1-3):	**9.28**
Simulated Spring Flow Volume (months 4-6):	**1.55**	Observed Spring Flow Volume (4-6):	**2.19**
Total Simulated Storm Volume:	**14.06**	Total Observed Storm Volume:	**13.74**
Simulated Summer Storm Volume (7-9):	**1.00**	Observed Summer Storm Volume (7-9):	**0.46**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-4.24**	10	
Error in 50% lowest flows:	**-14.94**	10	
Error in 10% highest flows:	**1.24**	15	
Seasonal volume error - Summer:	**29.26**	30	
Seasonal volume error - Fall:	**-5.20**	30	
Seasonal volume error - Winter:	**-1.57**	30	
Seasonal volume error - Spring:	**-40.89**	30	
Error in storm volumes:	**2.29**	20	
Error in summer storm volumes:	**53.93**	50	

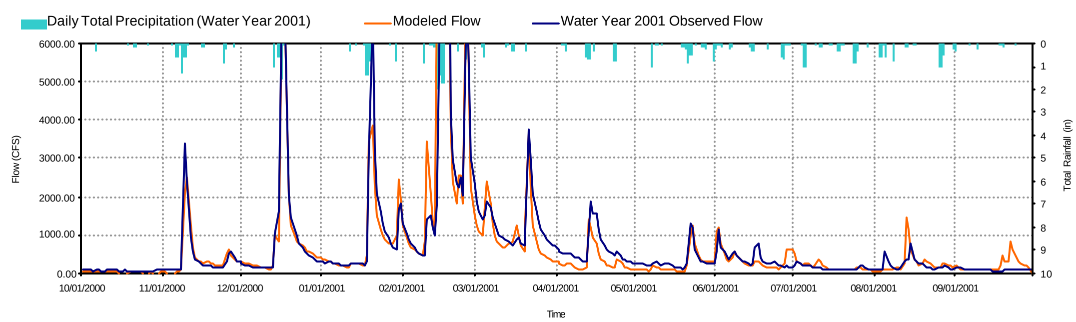


Figure 18. Water Year 2001 Flow Calibration Timeseries Chart at USGS gage 3434500, down-stream

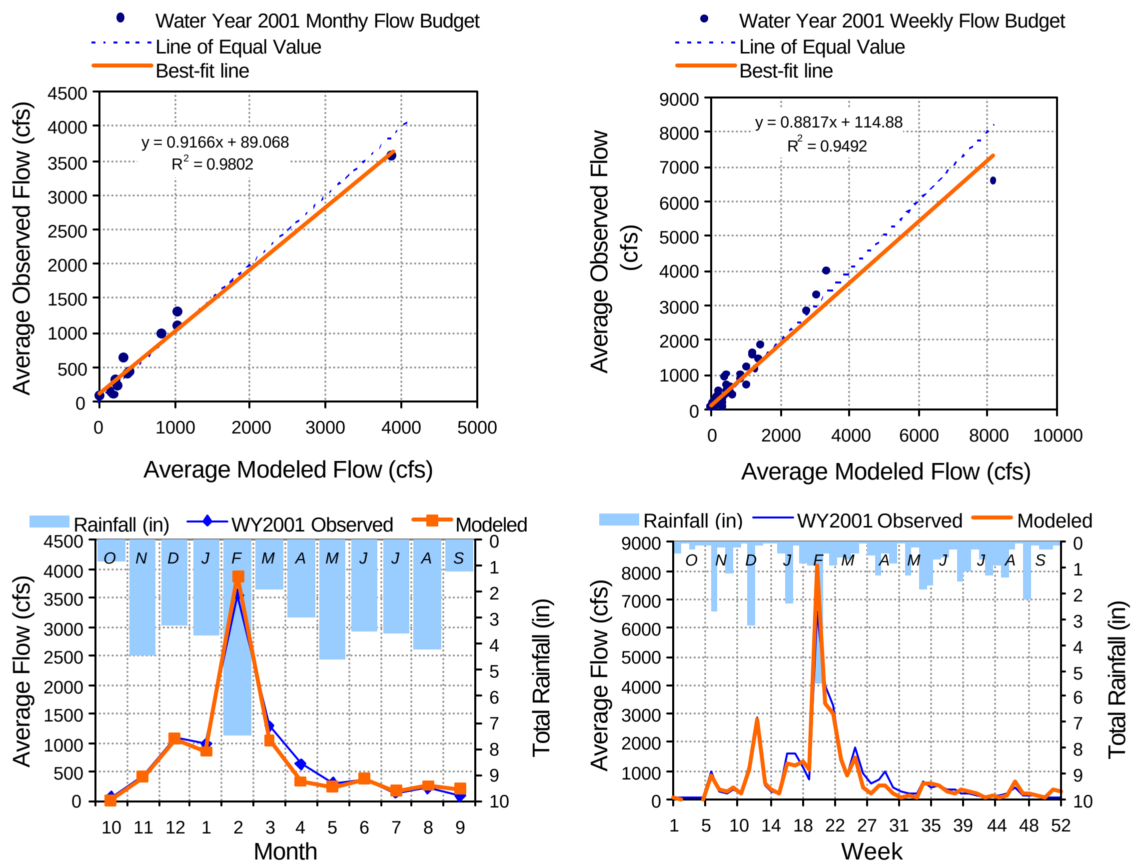


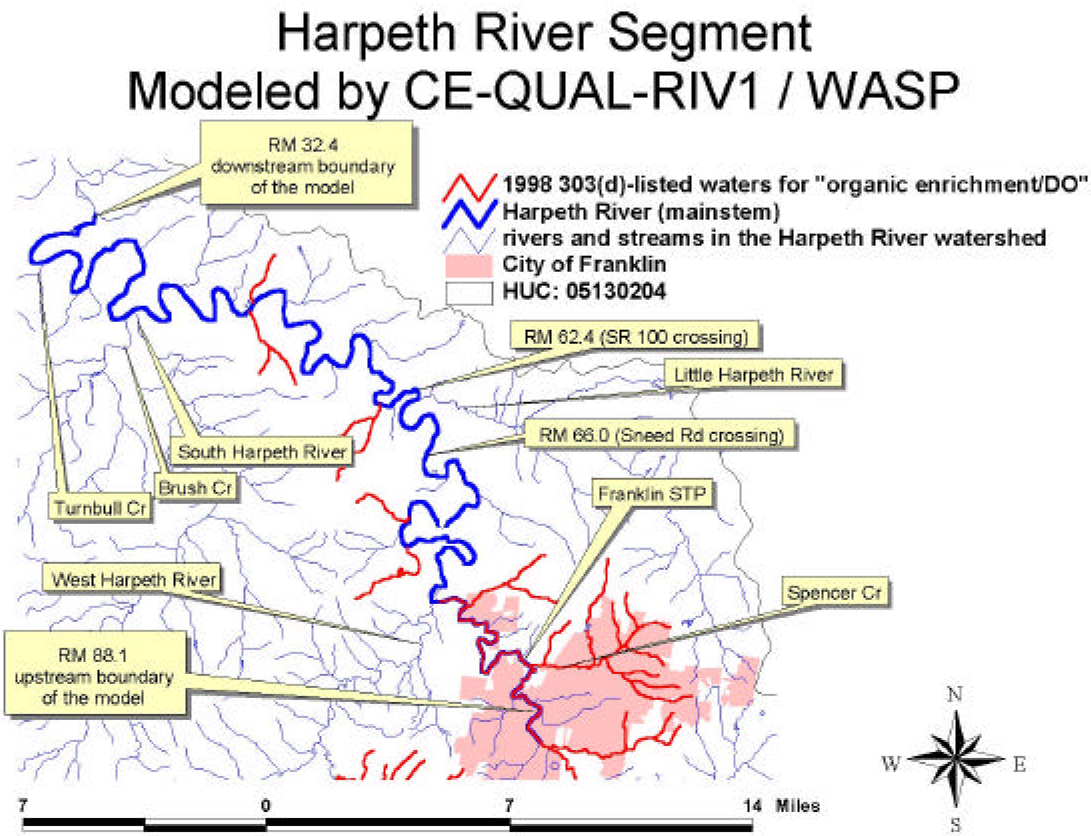
Figure 19. Water Year 2001 Flow Calibration Summary Charts at USGS gage 3434500, down-stream

The water quality was estimated by using the LSPC parameter values developed through previous calibrations in the region. The water quality for biochemical oxygen demand, nitrogen and phosphorus was simulated as general water quality associated with sediment, interflow and groundwater in the watershed. The predicted water quality values compared favorably to the few available observed values. The simulation involved constituent accumulation to a maximum limit and transport by overland flow according to precipitation events. The constituents were subjected to a generalized first-order decay once they entered a tributary stream.

CE-QUAL-RIV1 Modeling Effort

In order to provide hydraulic data to the water quality model, the application of a hydrodynamic model is required. EPA used a contractor to develop the application of the hydrodynamic model, CE-QUAL-RIV1, to the Harpeth River. It should be noted that a significant portion of the text from the hydrodynamic modeling section of this report comes from the draft CE-QUAL-RIV1 report authored by a sub-contractor for EPA (Martin, 2002). The objective of this portion of the modeling effort was the development of a hydrodynamic model for 55.7 miles of the mainstem of the Harpeth River (from RM88.1 to RM32.4) as seen in the figure below. The model was set-up in order that it can be linked with the WASP 6.0 water quality model.

Figure 20. Application of CE-QUAL-RIV1 to the Harpeth River



Model Selection

The hydrodynamic model selected for this application is CE-QUAL-RIV1 (Environmental Laboratory 1995). CE-QUAL-RIV1 is a one-dimensional (cross-sectionally averaged) hydrodynamic and water quality model, meaning that the model resolves longitudinal variations in hydraulic and quality characteristics and is applicable where lateral and vertical variations are small. CE-QUAL-RIV1 consists of two parts, hydrodynamic (RIV1H) and water quality (RIV1Q), of which only the hydrodynamic model was applied to the Harpeth River. The hydrodynamic model is typically used to predict one-dimensional hydraulic variations in streams and rivers with highly unsteady flows, although it can also be used for prediction under steady flow conditions.

RIV1H predicts flows, depths, velocities, water surface elevations and other hydraulic characteristics. The hydrodynamic model solves the St. Venant equations as the governing flow equations using the widely accepted four-point implicit finite difference numerical scheme.

The model that serves as the basis for CE-QUAL-RIV1 was originally developed at Ohio State University at the request of the EPA for predicting water quality associated with storm water runoff. Researchers at the U.S. Army Engineer Waterways Experiment Station (WES) were attracted to the model because it was fully dynamic for determining flow and water quality and it had several desirable numerical features, such as a two-point fourth-order scheme for accurately predicting the advection of water quality concentrations. The WES contracted Ohio State University to modify the model code to handle control structures. This modification, along with the unsteady flow feature, gave the model the versatility needed for simulating Corps of Engineers regulated stream/waterway projects. Subsequently, the updated version was tested at WES, and additional modifications and corrections were made, resulting in Version 1.0 of CE-QUAL-RIV1, released in 1991. WES further modified and supported CE-QUAL-RIV1, releasing Version 2.0 of the model in 1995 (Environmental Laboratory 1995).

The RIV1H model typically writes out hydraulic data to a linkage file for use by the quality component, RIV1Q. As part of a separate project, the RIV1H model has been modified to produce a linkage file compatible with the Water Analysis Simulation Program (WASP). WASP is the model selected for the water quality analysis of the Harpeth River. The robust hydrodynamics, coupled with the ability to write WASP compatible hydrodynamic linkage files, were the primary reasons for the selection of the RIV1H model for this application.

Review of Available Data

Geometric Data

The geometric data for the reach of the Harpeth River were provided in HEC-RAS format for 18 cross-sections between river miles 88.1, the upstream cross-section and river mile 32.4. The locations of the cross sections and downstream reach lengths are provided in Table 14. Note that some of the cross-sections are interpolated from available cross-sections using topographic data.

Additional geometric information was obtained from data provided in Flood Insurance Study Reports by the Federal Emergency Management Agency (FEMA, 1993, 1999, 2001). The reports included plots of predicted water surface elevations for a series of high flow events as well as bottom elevations for the study reach. Cross-sectional data were not available. Bottom elevations were estimated from the profile plots and used to estimate bottom elevations for all cross-sections in this study.

The available cross-sectional data were processed in HEC-RAS Version 3.0 and then output for conversion to RIV1H format. The conversion was accomplished using software developed as part of this project. The HEC-RAS interpolated bottom elevations were then replaced with bottom elevations taken from FEMA profile plots. Comparisons between the EPA provided bottom elevations, bottom elevations from FEMA studies, and the bottom elevations used in this study are provided in Figure 21 to Figure 23.

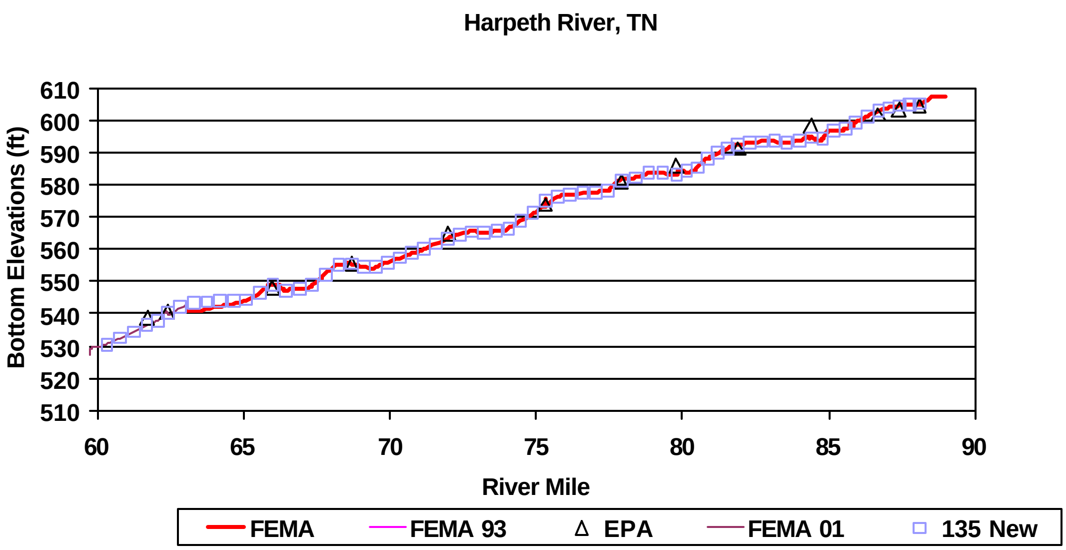


Figure 21. Comparisons of EPA provided and FEMA bottom elevations with those used in the application of CE-QUAL-RIV1 to the Harpeth River, for river miles 90-60.

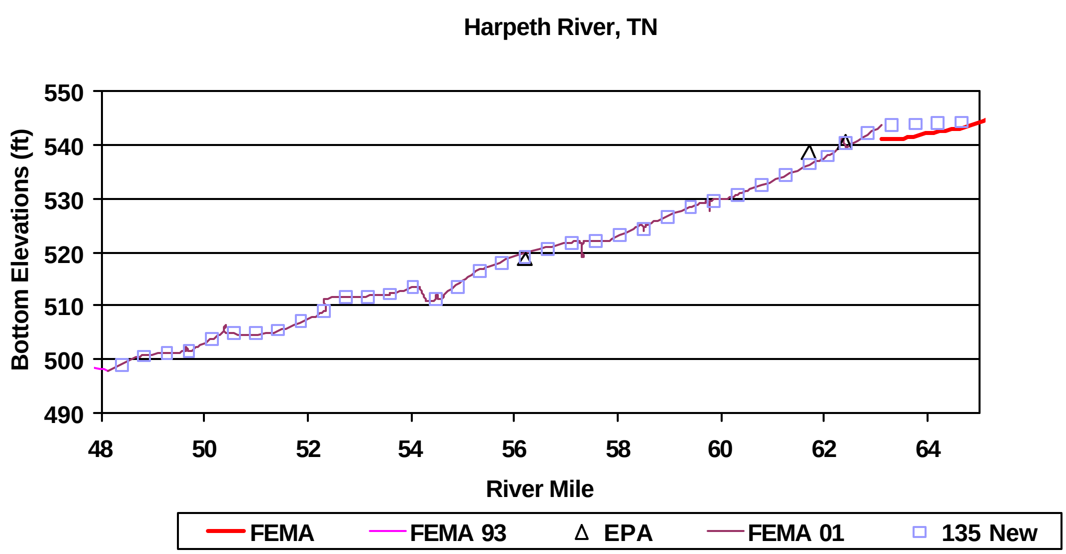


Figure 22. Comparisons of EPA provided and FEMA bottom elevations with those used in the application of CE-QUAL-RIV1 to the Harpeth River, for river miles 64-48.

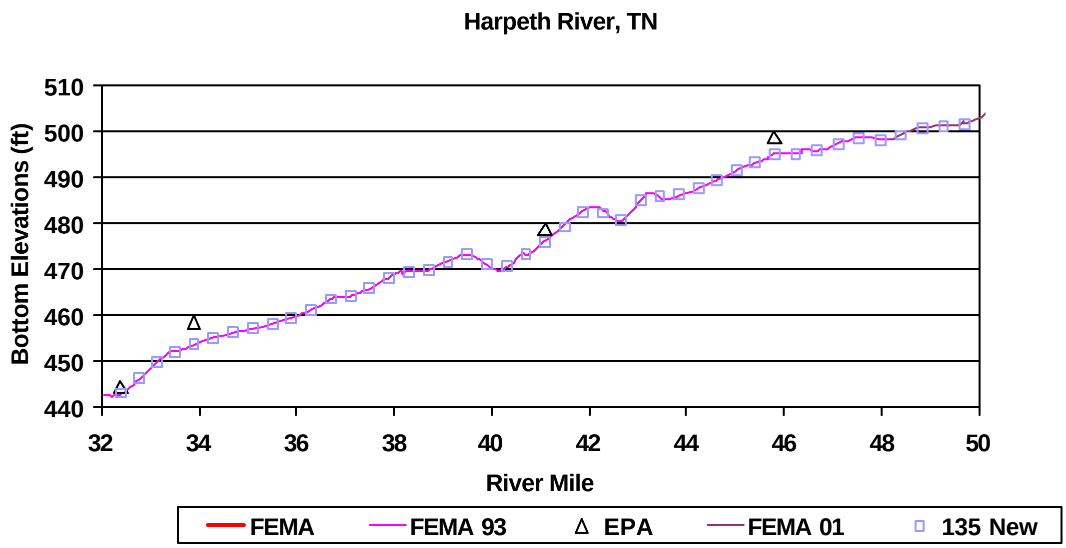


Figure 23. Comparisons of EPA provided and FEMA bottom elevations with those used in the application of CE-QUAL-RIV1 to the Harpeth River, for river miles 48-32.

Table 14. Harpeth River Cross-section locations

Downstream Reach Lengths		
	River Mile	Length (ft)
1	88.1	3696
2	87.4	3696
3	86.7	12144
4	84.4	13200
5	81.9	11088
6	79.8	10032
7	77.9	13728
8	75.3	17424
9	72.0	17424
10	68.7	14256
11	66.0	19008
12	62.4	3696
13	61.7	29040
14	56.2	54912
15	45.8	24816
16	41.1	38016
17	33.9	7920
18	32.4	0

Harpeth River Flow Data

Flow and stage data were provided for the model application at 15-minute intervals for the following stations:

- USGS Station 3432350 at River mile 88.1: Harpeth River at Franklin, TN.
- USGS Station 3432390 at river mile 85.4: Spencer Creek near Franklin, TN.
- USGS Station 3432400 at river mile 84.4:Harpeth River below Franklin, TN
- USGS Station 3433500 at river mile 62.4:Harpeth River at Bellevue, TN, and
- USGS Station 3434500 at river mile 32.4: Harpeth River near Kingston Springs, TN

Data were provided for the stations indicated above for the years 1992-2001, with the exception of the Spencer Creek station. The flow data from Station 3432350, Harpeth River at Franklin, was used as the model upstream boundary condition. The flow and stage data at stations 3432400, 3433500, and 3434500 were used for model calibration and evaluation. A rating curve, based on information provided was used for model boundary condition at river mile 32.4.

A limited analysis of the available flow data was completed prior to its use in the modeling study. The available daily averaged flow data was downloaded from the USGS web site for each of the above stations. A limited comparison was then made between the 15-minute and daily averaged flows to aid in validating the available data. For the water years 1999 and 2000, the flows were also analyzed graphically and statistically. Probability plots for the 15-minute flow data over each of these years are provided below in Figure 24 and Figure 25. The plots illustrate the large differences in flows between the upstream and downstream gaging stations, indicating the importance of tributary inflows in this river reach.

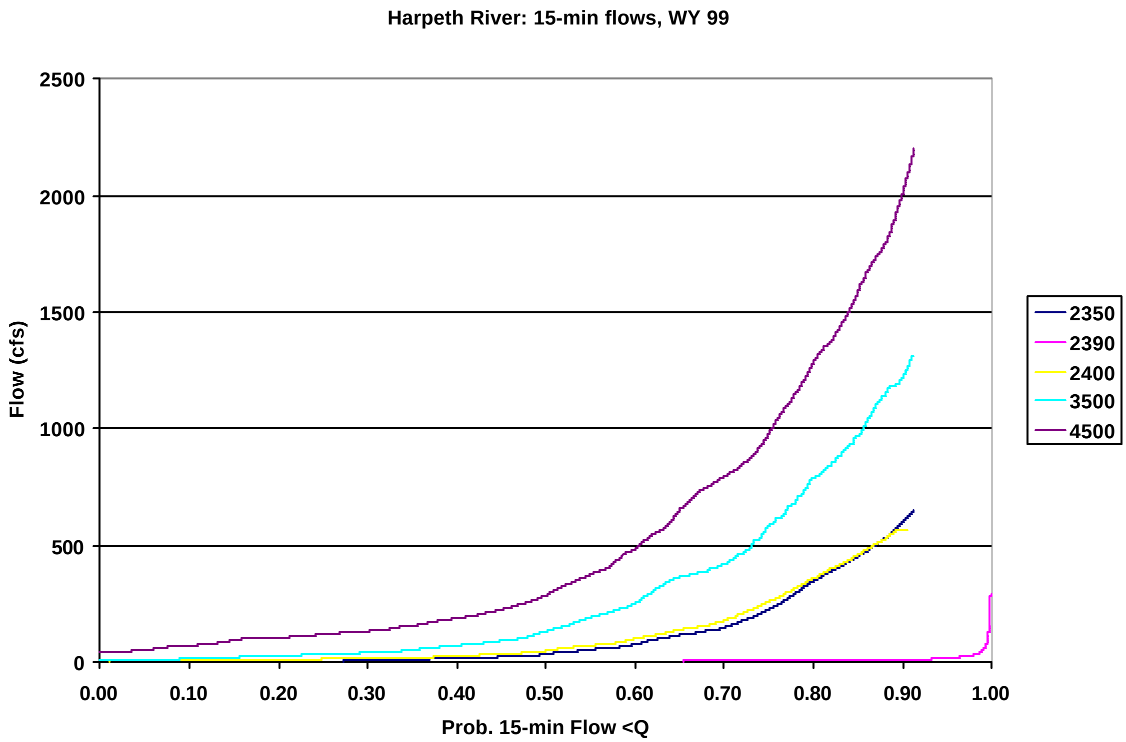


Figure 24. Probability distribution of 15-minute Harpeth River flows for Water Year 1999

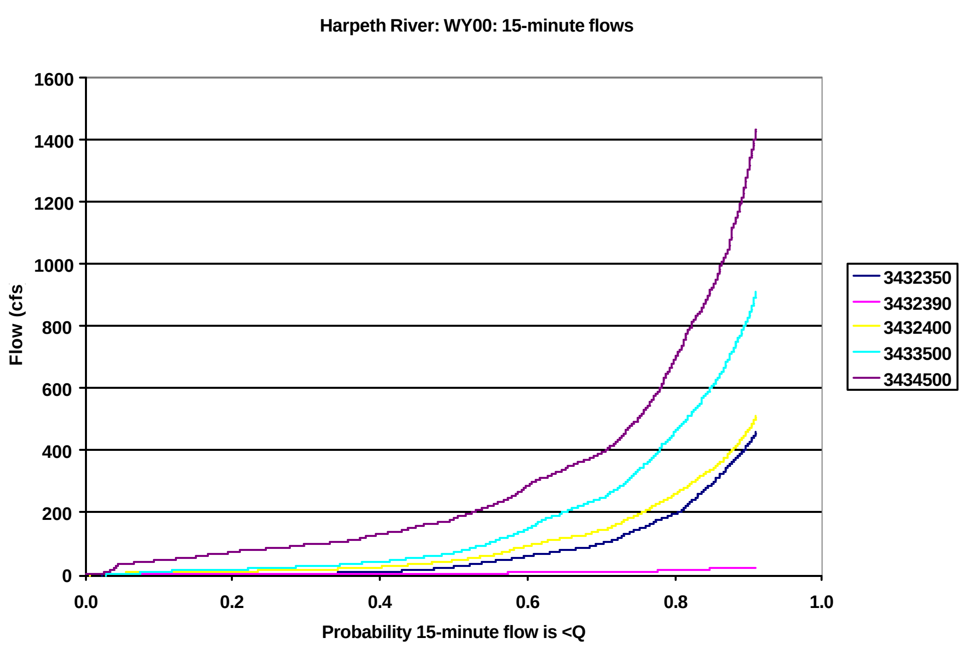


Figure 25. Probability distribution of 15-minute Harpeth River flows for Water Year 2000

Tributary Flow Data

For the model calibration, predicted tributary flows from the LSPC model were input as boundary flows to the CE-QUAL-RIV1 model (see listed tributaries in Table 8). In addition, flows from the Franklin STP represent a point source. Additional point sources were considered (i.e., the Lynnwood STP at RM77.9, the Cartwright Creek Utility District STP at RM68.8, and the Harpeth Valley Utility District at RM57.8). However, the flows from these facilities were considered negligible in comparison to other flows and were not included in the hydraulic simulations. For the remaining tributary sources, some represented a discrete source, as indicated by a specific river mile location, while others represented distributed sources. For distributed sources, a range of river miles was provided as well as a recommendation for a specific river mile if these sources were to be specified as a point source in the hydraulic simulation (Table 14).

Table 15. Tributary Locations

Tributary	At River Mile	From River Mile	To River Mile
Franklin STP	85.3		
Spencer Creek	85.4		
Urban Streams	86.8	88.1	85.4
Lynnwood Branch	80.0	85.4	78.7
West Harpeth River	78.7		
Murray Branch	73.4	78.7	62.5
Little Harpeth River	62.5		
Newsome-Beech	50.0	62.4	43.6
South Harpeth River	43.6		
Brush Creek	44.3		
Hanna Branch	37.5	43.6	35.2
Turnbull Creek	35.2		
Unnamed Tributaries	33.1	37.5	33.1

For the application of CE-QUAL-RIV1, all tributary sources are specified as point sources to the model. That is they are each applied to a single cross-section. The cross-section at which they are applied is that nearest to the river mile specified in the above table. For the Franklin STP and Spencer Creek, the tributary flows were added and applied to a single cross-section.

As indicated previously, the tributary flows comprise a considerable portion of the total flows to the Harpeth River. For example, in water year 2000 the 50-percentile 15-minute flows increased from 27 cfs at the Franklin gage (station 3432500) to 181 cfs at the downstream boundary (station 3434500, Figure 25). The relative magnitude of the tributary inflows is illustrated in Table 16 to Table 18 for the water years 1999-2001, respectively. Water year 1999 is considered a dry year, while water year 2000 is considered a dry to average year. These tables indicate the highly variable flow magnitudes between tributary sources. The tributary sources were also highly variable in time.

Table 16. Tributary flow data for Water Year 1999

Tributary source	max	min	median	average
Franklin STP	31.98	0.01	5.63	6.52
Spencer Cr	964.27	0.00	3.95	21.36
Urban Streams	548.60	0.00	2.55	12.06
Lynnwood Br	365.29	0.00	4.24	13.31
West Harpeth R	4053.58	0.00	47.03	147.65
Murray Br	758.88	0.00	8.80	27.64
Little Harpeth	1589.16	0.00	18.44	57.88
Newsome-Beech-Trace Creeks	2147.79	0.00	22.90	57.46
South Harpeth R	3186.57	0.00	33.97	85.25
Brush Cr	1338.40	0.00	14.27	35.81
Hannah Br	483.77	0.00	5.16	12.94
Turnbull Cr	6215.00	0.00	66.25	166.28
unnamed tribs	296.46	0.00	3.16	7.93

Table 17. Tributary flow data for Water Year 2000

Tributary source	max	min	median	average
Franklin STP	211.02	0.41	6.82	8.03
Spencer Cr	1093.00	0.77	5.60	14.49
Urban Streams	664.26	0.00	4.36	11.37
Lynnwood Br	236.86	0.00	2.27	9.52
West Harpeth R	2628.42	0.00	25.21	105.68
Murray Br	492.07	0.00	4.72	19.79
Little Harpeth	1030.44	0.00	9.88	41.43
Newsome-Beech-Trace Creeks	1080.53	0.00	16.03	36.29
South Harpeth R	1603.12	0.00	23.78	53.84
Brush Cr	673.33	0.00	9.99	22.61
Hannah Br	243.38	0.00	3.61	8.17
Turnbull Cr	3126.69	0.00	46.38	105.00
unnamed tribs	149.14	0.00	2.21	5.01

Table 18. Tributary flow data for Water Year 2001

Tributary source	max	min	median	average
Franklin STP	283.90	1.16	6.61	7.88
Spencer Cr	1402.90	1.15	5.57	16.41
Urban Streams	660.36	0.00	5.72	15.20
Lynnwood Br	512.29	0.00	4.12	12.05
West Harpeth R	5684.79	0.00	45.66	133.73
Murray Br	1064.27	0.00	8.55	25.04
Little Harpeth	2228.66	0.00	17.90	52.43
Newsome-Beech-Trace Creeks	1541.86	0.00	16.32	43.01
South Harpeth R	2287.58	0.00	24.21	63.81
Brush Cr	960.81	0.00	10.17	26.80
Hannah Br	347.29	0.00	3.68	9.69
Turnbull Cr	4461.63	0.00	47.22	124.45
unnamed tribs	212.82	0.00	2.25	5.94

Other available data

Additional data provided to support the model application included instantaneous snapshots of fow and stage at selected locations for the period of 8/22/2000-8/24/2000 and for 4/18/2001. In addition, time-of travel studies were conducted at selected locations from the water quality studies conducted by EPA in 2000 and 2001 as well as TDEC in 1995. These data were used in the evaluation of the hydrodynamic model.

Model Set-up and Testing

Geometry

Geometric data for the reach of the Harpeth River was provided in HEC-RAS format for the locations listed in Table 14. The existing cross-sections were insufficient for the hydraulic application. The additional cross-sections needed were obtained by interpolating between existing cross-sections using the interpolation scheme included in HEC-RAS. Once the interpolation was completed, the HEC-RAS cross-sectional data were converted to RIV1H format using a FORTRAN program developed for this application.

A number of interpolation schemes were attempted, varying in the total number of cross-sections from 70 to 135. The final geometric configuration adapted consisted of 135 cross-sections, with downstream lengths varying from 1848 to 3000 feet.

Boundary Conditions

The boundary condition data required for RIV1H simulations includes the upstream boundary flows, lateral (tributary) flows, and a downstream boundary condition. The upstream and tributary flows are specified in ASCII input files (*.bcf and *.laq files). The downstream boundary condition may be specified in files, or in the case of a constant head boundary or rating curve, in the RIV1H input file.

The upstream boundary conditions were taken from the 15-minute flow data provided for the USGS Franklin station (station 3432500). These data were processed to RIV1H format for each of the water years 1992-2001 using a FORTRAN program developed for this project. To maintain stability, a minimum flow of 1 cfs was imposed for all upstream boundary flows.

Tributary flows are specified to RIV1H as a lateral inflow in units of cfs/ft. The lateral inflows specified at a specific cross-sectional location are then distributed by RIV1H based upon the mid-point distance to the adjacent upstream and downstream cross-sections. To process the tributary inflows provided to RIV1H format, it was necessary to first specify the location of the inflow (cross-section i) and then convert the units from cfs to cfs/ft by dividing by the appropriate distance ($0.5\Delta x_i+0.5\Delta x_{i-1}$). The conversion and creation of the RIV1H input files for each of the years for which data were provided was accomplished using a FORTRAN program developed for this application. The RIV1H convention also has implications for the specification of loads in the water quality model application, since each lateral flow will be distributed to two WASP segments.

The downstream boundary condition for this application was a rating curve. The rating curve was based upon USGS data for that station.

Initial Conditions

Initial conditions are required for the RIV1H simulations. Initial conditions were developed first by running HEC-RAS using steady-flow conditions reflective of the initial upstream boundary condition for the particular simulation. The resulting predicted depths were extracted from the HEC-RAS results and input to the RIV1H model input file. For lateral inflows, the RIV1H model was run with the lateral inflows ramped from a zero flow condition to a steady condition reflective of the initial lateral inflow condition. The initial conditions (flows and depths) were then replaced by the steady flow results.

Model Calibration

Following testing of input data as described in the project preliminary report, input data sets were prepared and initial conditions developed for dynamic simulations for the purpose of model calibration. Model calibration concentrated on the 2000 and 2001 water years. For both water years, comparisons were made to available flow and water surface elevation data at three gaging stations:

- USGS Station 3432400 at river mile 84.4: Harpeth River Below Franklin, TN,
- USGS Station 3433500 at river mile 62.4:Harpeth River At Bellevue, TN, and
- USGS Station 3434500 at river mile 32.4: Harpeth River Near Kingston Springs, TN

The calibration effort, in part consisted of

- Finalizing model geometry by determining the number and location of cross-sections that were most numerically stable and produced the most reasonable results. A number of cross-sectional configurations were attempted, with the final configuration consisting of 135 cross-sections.
- Smoothing model input to allow the model to run for the calibration periods. For both calibration periods there were some periods where the model became unstable due to a combination of boundary and tributary inflow conditions. Some smoothing of model input was required to allow the model to run through these periods.
- Adjusting model roughness coefficients. It was determined that relatively high roughness coefficients (Manning's n) were required to approximate the observed velocities and times of travel under low flow conditions. However, uniformly high roughness coefficients resulted in excessive times of travel during higher flow events. A variable roughness coefficient was input so that the roughness coefficient decreased linearly with increasing depth from 0.15 (at a zero depth) to a minimum value of 0.03

Comparisons of predicted flows for the 2000 and 2001 water years, respectively, are illustrated in Figure 26 to Figure 31. Comparisons of predicted water surface elevations for the 2000 and 2001 water years respectively are provided in Figure 32 to Figure 37. Generally, the predicted magnitude and timing of flows are in close agreement with those observed at the three gaging stations. Comparisons with predicted stage (elevations) are reasonable, but differences are evident. Differences at USGS gage 3434500 are attributed in part to the use of a rating curve of the form depth=aQ^b which allowed for a relatively poor representation of the actual rating curve (r^2 = 0.88).

Comparisons of predicted and observed velocities and travel times for the 2000 and 2001 special studies are provided in Figure 38 to Figure 41. The water velocities are overestimated for 2000, and resulting times of travel underestimated. Comparisons for 2001 are in much closer agreement.

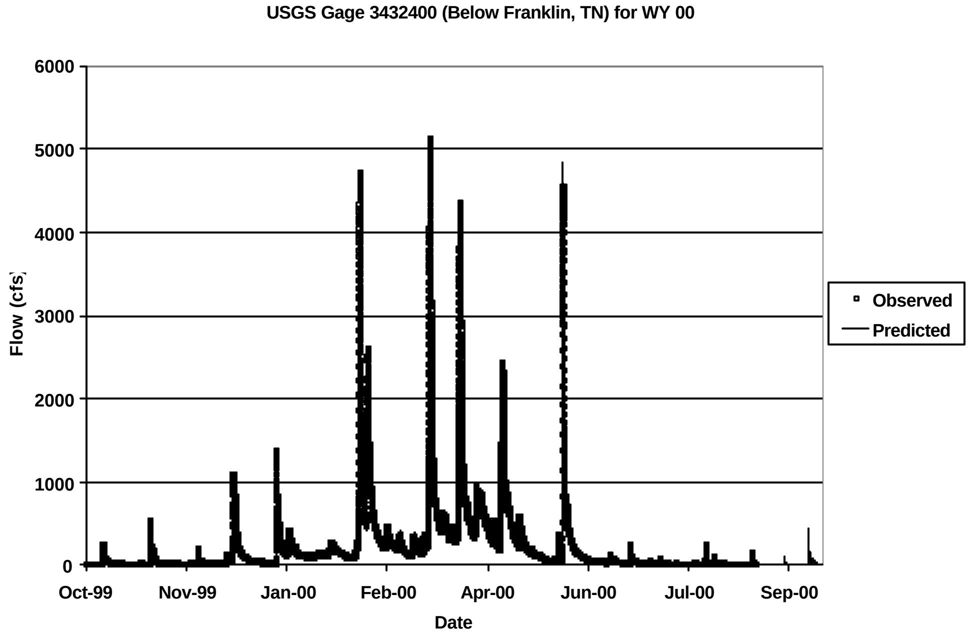


Figure 26. Comparison of observed and predicted flows at USGS gage 3432400 for water year 2000.

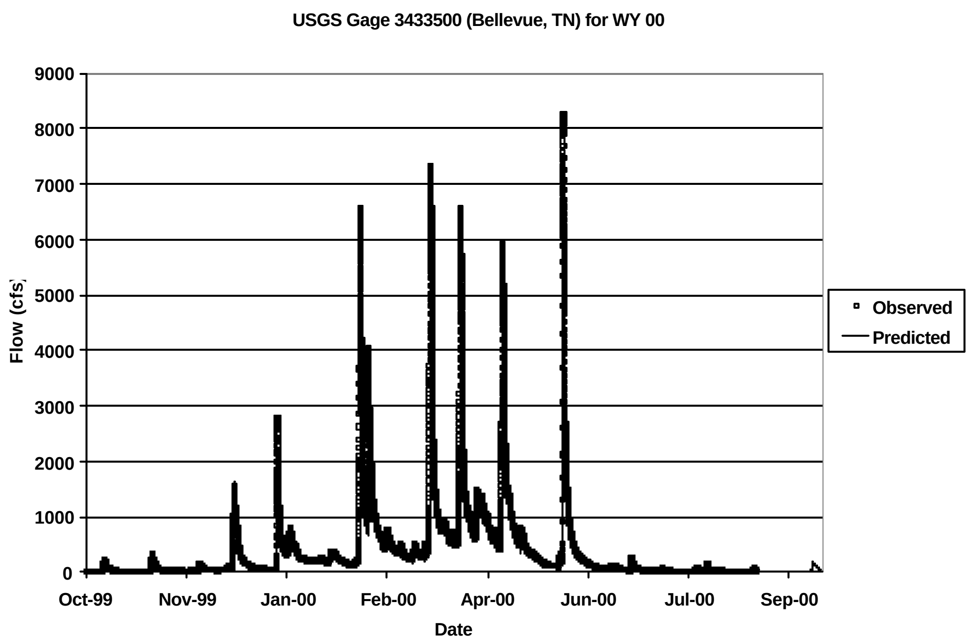


Figure 27. Comparison of observed and predicted flows at USGS gage 3433500 for water year 2000.

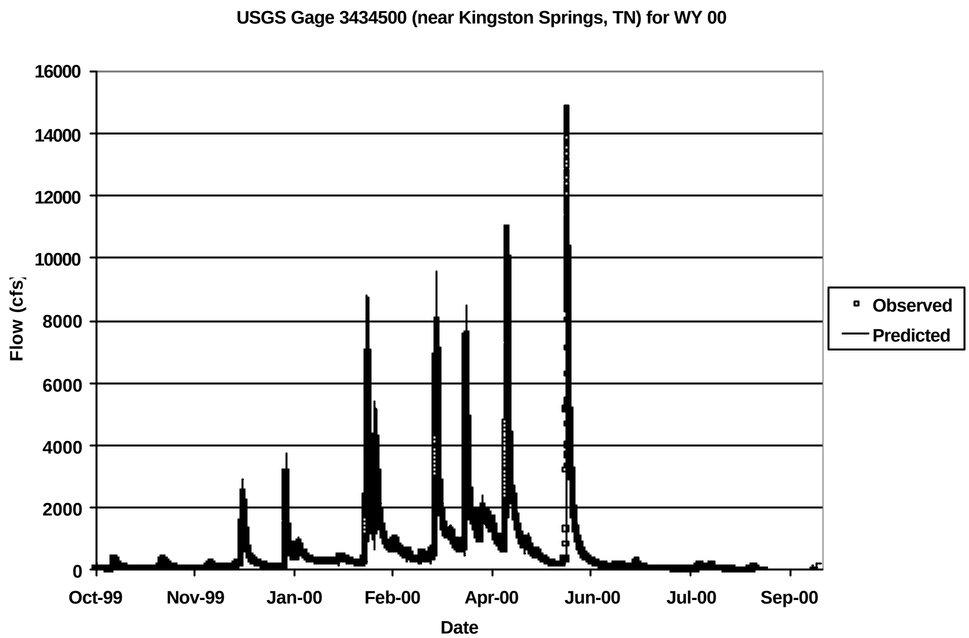


Figure 28. Comparison of observed and predicted flows at USGS gage 3434500 for water year 2000.

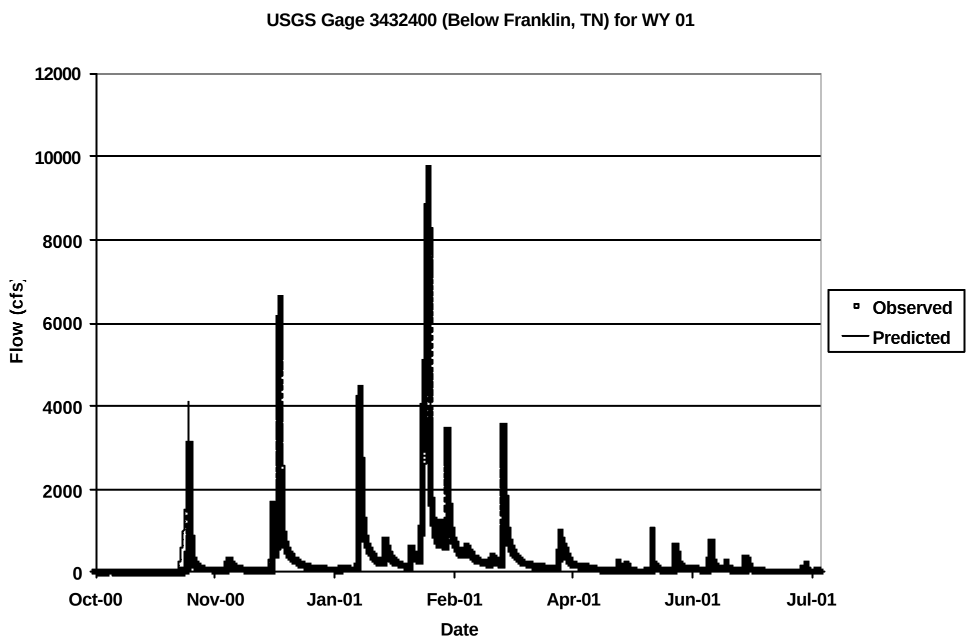


Figure 29. Comparison of observed and predicted flows at USGS gage 3432400 for water year 2001.

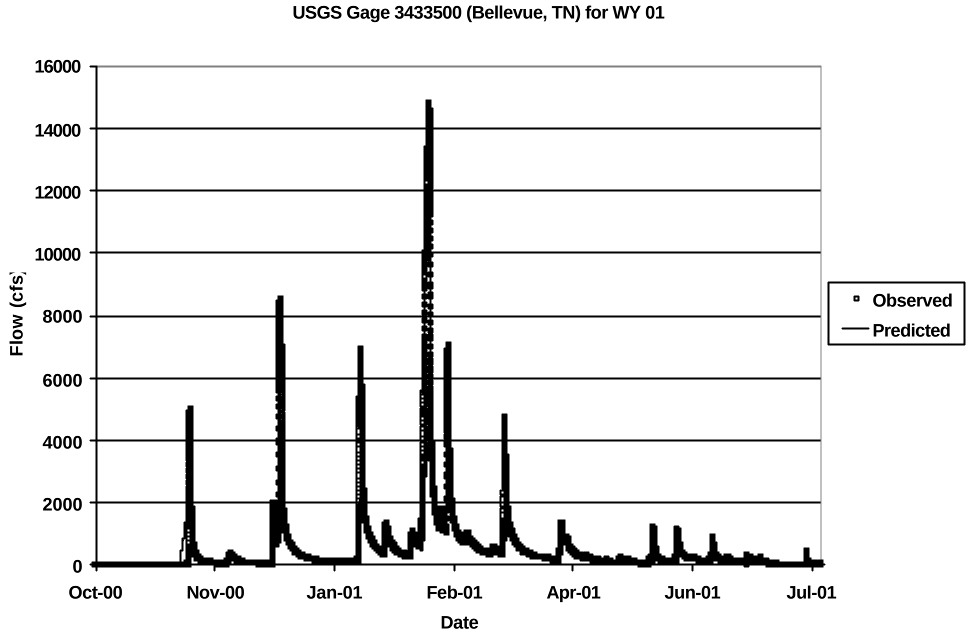


Figure 30. Comparison of observed and predicted flows at USGS gage 3433500 for water year 2001.

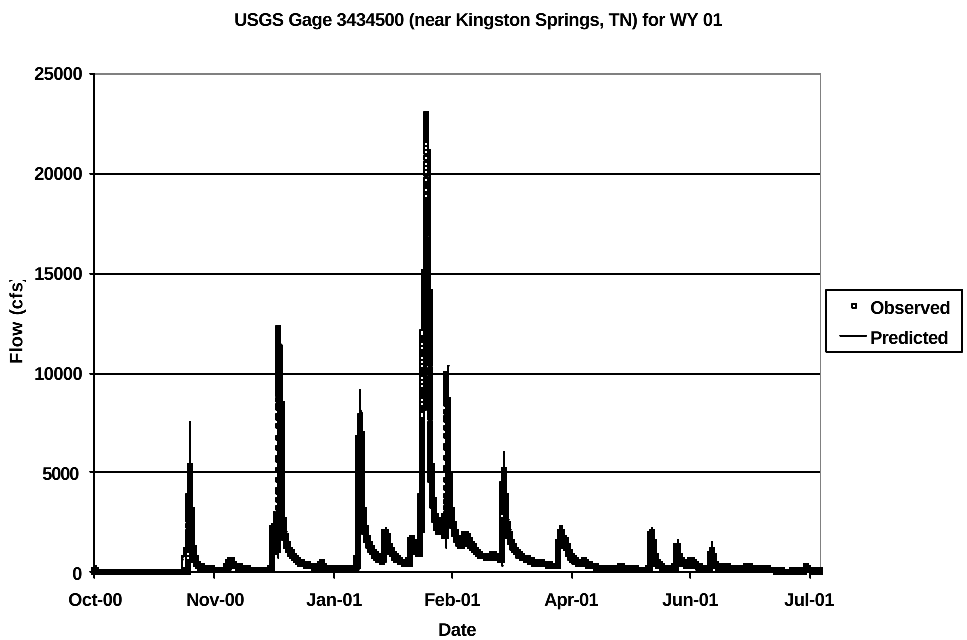


Figure 31. Comparison of observed and predicted flows at USGS gage 3434500 for water year 2001.

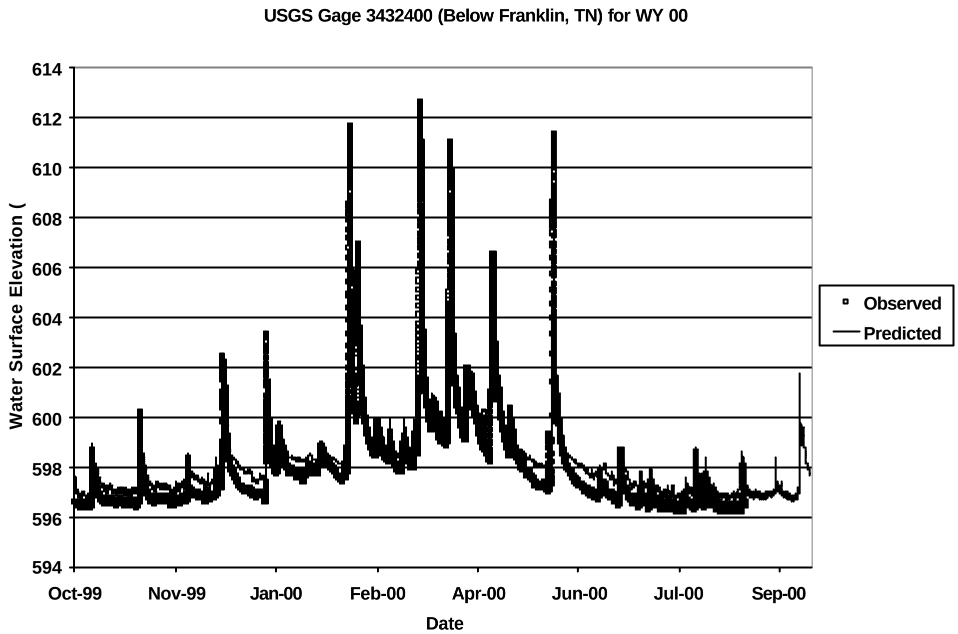


Figure 32. Comparison of observed and predicted water surface elevations at USGS gage 3432400 for water year 2000.

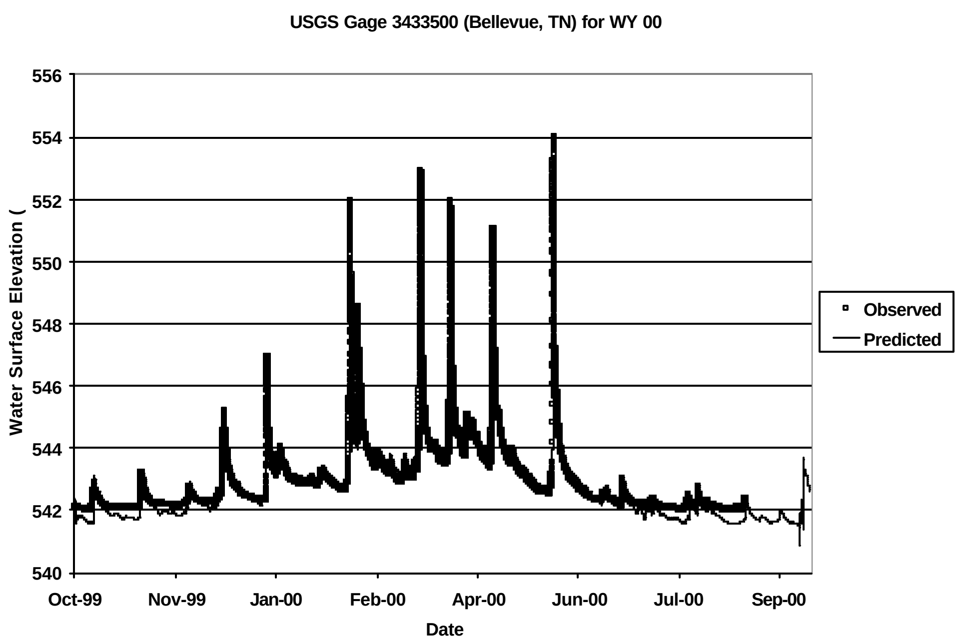


Figure 33. Comparison of observed and predicted water surface elevations at USGS gage 3433500 for water year 2000.

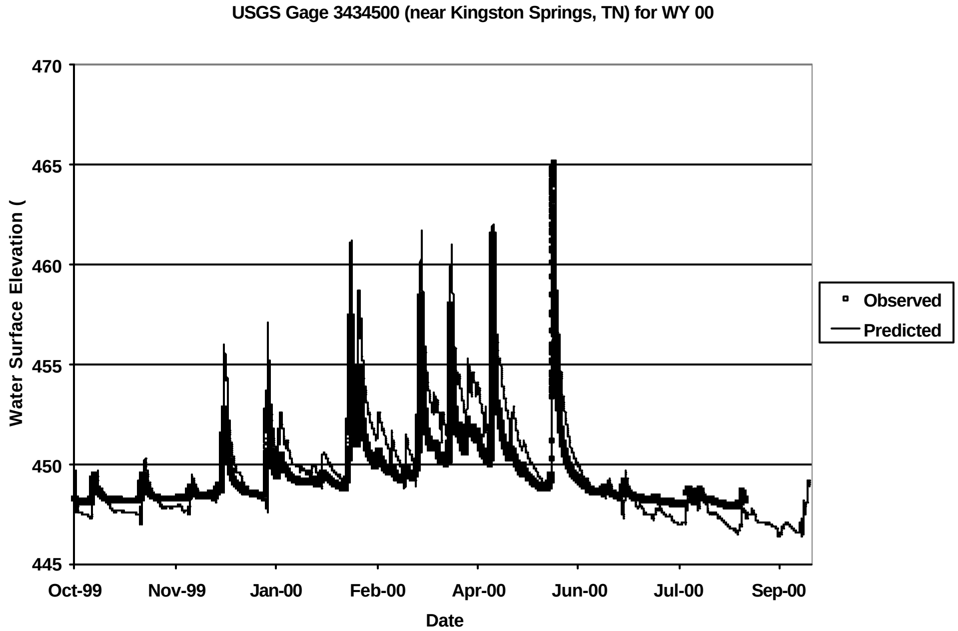


Figure 34. Comparison of observed and predicted water surface elevations at USGS gage 3434500 for water year 2000.

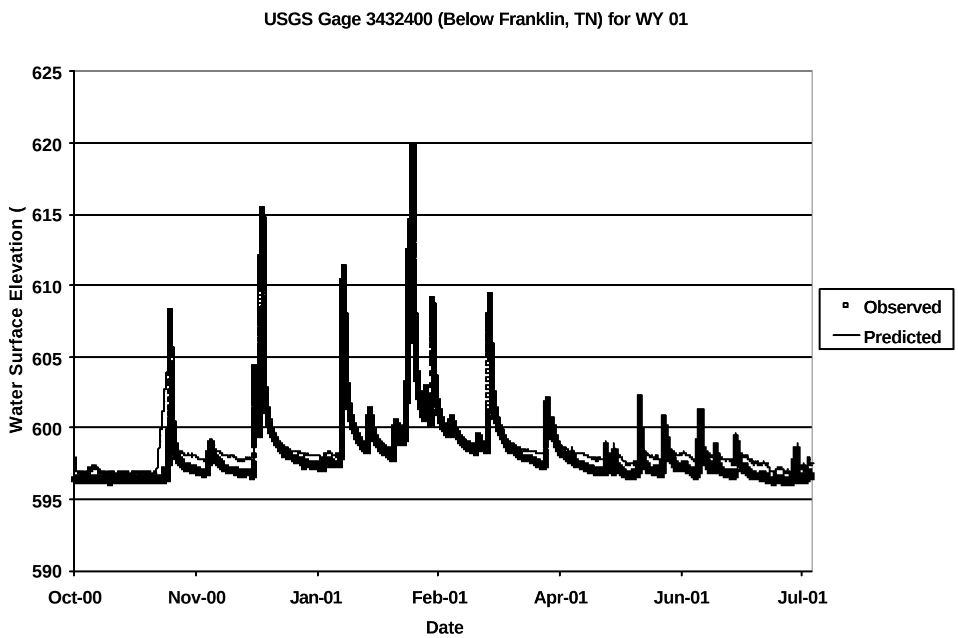


Figure 35. Comparison of observed and predicted water surface elevations at USGS gage 3432400 for water year 2001.

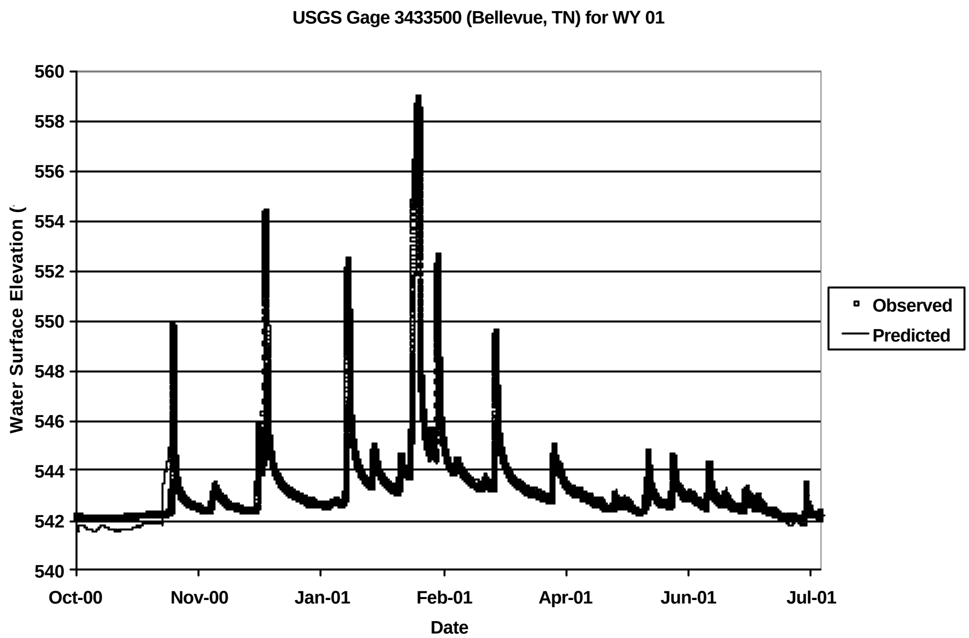


Figure 36. Comparison of observed and predicted water surface elevations at USGS gage 3433500 for water year 2001.

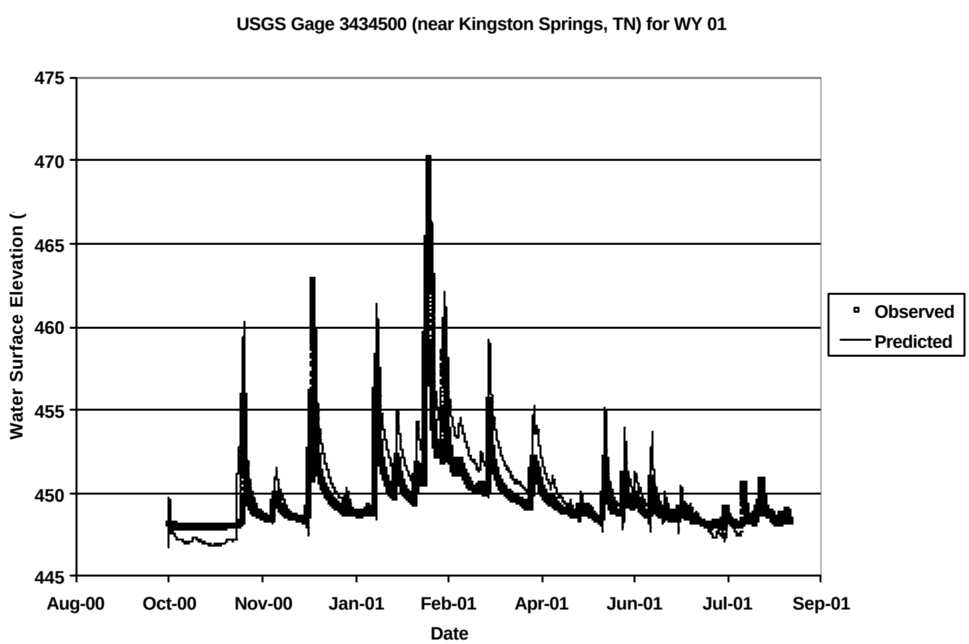


Figure 37. Comparison of observed and predicted water surface elevations at USGS gage 3434500 for water year 2001.

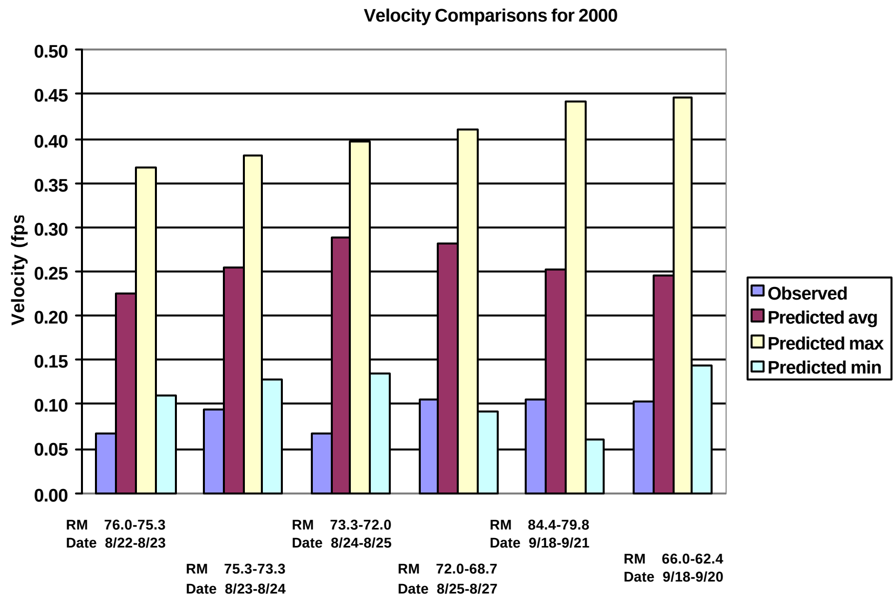


Figure 38. Comparison of predicted water velocities with those observed during the 2000 time of travel studies.

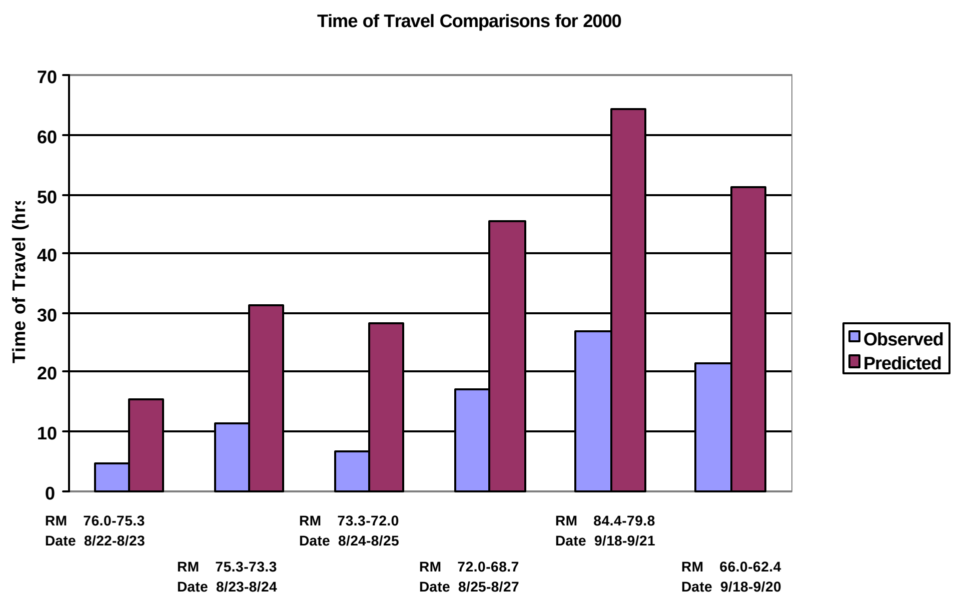


Figure 39. Comparison of predicted and observed time of travel from the 2000 EPA studies.

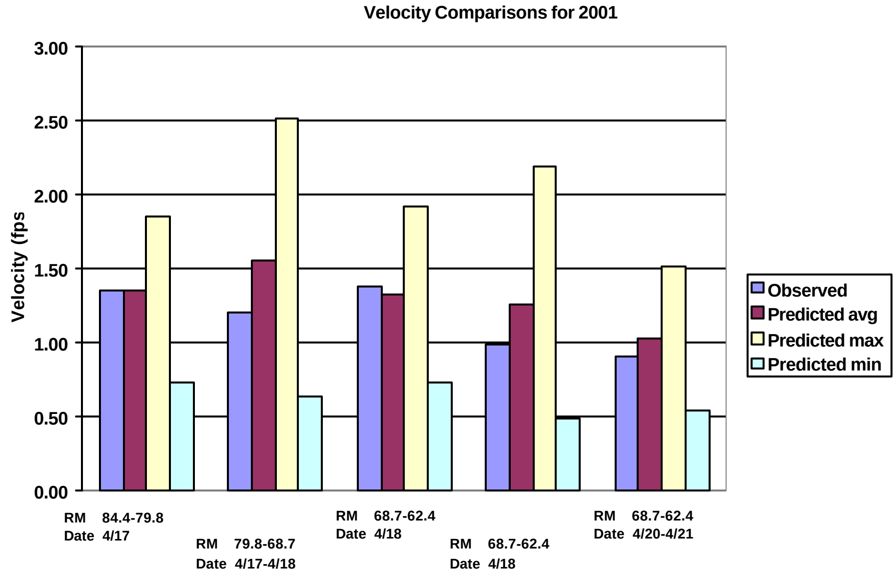


Figure 40. Comparison of predicted water velocities with those observed during the 2001 time of travel studies.

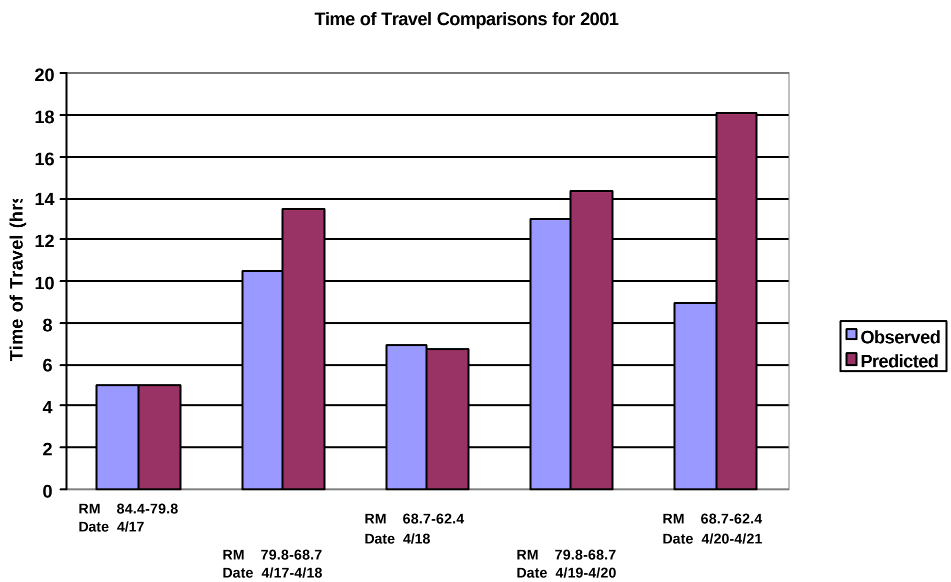


Figure 41. Comparison of predicted and observed time of travel from the 2000 EPA studies.

Model Application

Once the calibration was completed, the model was applied to estimate flows for the water years 1992-2001. Estimated flows for the upstream boundary and tributary inflows were provided from the predictions of the LSPC hydrologic model for each of these years. The hydrodynamic model application first consisted of reviewing and testing of the estimated inflows, in comparison to data previously provided for the model calibration. Then, for each water year:

- The LSPC model predictions for the upstream boundary and lateral inflows were processed to create input files for the RIV1 hydrodynamic model (*.bcf and *.laq input files) using software developed for this application.
- The RIV1 model input files were run under steady flow conditions from an initial condition known to be stable to the initial upstream boundary and tributary inflows in order to determine appropriate initial conditions for the respective water year. The initial input conditions for the respective water year were then taken from the model predictions at the end of the steady flow simulation.
- RIV1 simulations were performed for each year. During the course of each year, certain combinations of boundary and tributary inflows were determined to produce numerical instabilities. For these specific events, smoothing of input data was required in order to allow the model to run through these periods. Generally, the number of these events for any particular water year was less than four.

WASP Linkage Description and Input Requirements

In order to couple the WASP model with the CE-QUAL-RIV1 model, linkage routines were developed between the two models. The routines result in a file being created by RIV1 in the format of the DYNHYD linkage files commonly used in the application of WASP. Limited testing of these routines was conducted using the model simulations for the Harpeth River. A description of the routines and input requirements is provided below.

The input to the CE-QUAL-RIV1 hydrodynamic model and WASP water quality model were not changed from the original input requirements. All additional input required for the implementation of the linkage routines was incorporated in the RIV1H.CTL (control file). The control file was modified, as illustrated below, to include three additional lines of input. The first two lines are descriptive. They are read but not used by the linkage routines. The third additional line contains three input variables (fields of A6,2I6), used by the modified model:

- Wasp Switch: If this variable is set to “WASP” a hydrodynamic linkage file (in ASCII format) compatible with WASP will be created. If set to “RIV1” a linkage file compatible with the RIV1 water quality code will be created. Otherwise, linkage files will not be created.
- ISKIP: This variable indicates the number of time steps over which the flows will be arithmetically averaged and output to the linkage file. Initial volumes are written to the linkage file. The initial volumes are then followed flows averaged over ISKIP time steps (corrected for continuity)

and then volumes at the end of the averaging period. The time step specified in the linkage file for use by WASP is the hydrodynamic time step multiplied by ISKIP.

- ISTART: This variable indicates the time, as a multiple of the hydrodynamic time step, at which the initial volumes will be written to the linkage file. For example, if ISTART=100, then initial data are written to the linkage file on the 100th hydrodynamic time step. The start time specified in the linkage file is the start time for the hydrodynamic simulation plus ISTART*DT, where DT is the hydrodynamic time step. The end time written to the linkage file is based upon that specified in the CE-QUAL-RIV1 input (converted to seconds)

Example RIV1H.CTL File:

```
INPUT FILE     test_d.inp
LATERAL INFLOW JM_RECT.LAQ
XSECT TABLR
WASP  INPUT
123456123456123456
  WASP    11   300
```

For the implementation of the hydrodynamic linkage, the CE-QUAL-RIV1 hydrodynamic model was modified to:

- Read the revised input in the control file
- Create either a binary (RIV1 water quality model) or formatted linkage file, if the option is selected to create a WASP linkage file.
- Call the linkage routine (subroutine LINKER) once the number of time steps equals ISTART, at which time time-invariant information is written to the linkage file as well as the initial volumes.
- Call the linkage routine each subsequent time step

For the implementation of the linkage routine, revisions to both the CE-QUAL-RIV1 hydrodynamic model and include file (RIV1H.CMN) were required. In addition, a subroutine (linker) was created to develop the required input and write the results to the ASCII linkage file for the WASP model. The subroutine is first called once the number of time steps (ITIME) in the hydrodynamic simulation equals ISTART. On the initial call to the subroutine, the algorithm

- Loops over the RIV1 reaches, and cross-sections within each reach, to determine the number of WASP segments and the flow mapping for reach boundaries and internal flows.
    - o The segments are numbered consecutively within and between reaches. The number of segments within a reach

is typically the number of cross-sections minus one. The ordering of the reaches, and the resulting segments, is based upon the sorting routines used by RIV1.

- The reach boundary and internal flows, at each cross-section, are then counted and the WASP segment mapping determined (the mapping to specify the source and destination of flows at a RIV1 cross-section in terms of WASP segment numbers, where a boundary segment is indicated by a 0).
  - Note that if a reach feeds into the upper boundary of another reach (FEEDS is positive and JNODE is zero, see RIV1 input), only the flows at the end of the upstream reach are used, and it is assumed that the outflow of the upstream reach is equal to the inflow of the downstream, receiving, reach.
  - If a tributary feeds into a cross-section other than the upper cross-section of a reach (FEEDS is positive and JNODE not equal to zero,), then the outflow of the reach is mapped to the appropriate segment numbers in the receiving reach. As implemented in RIV1, half of the tributary reach outflow is distributed above the cross-section specified by JNODE and half below it. Correspondingly, in the linkage routine, half of the tributary flow is specified to the WASP segment above the cross-section and half to the downstream segment.

- Computes the initial segment volumes as the product of the average of the cross-sectional areas at each end of the segment and the distance between the cross-sections
- Computes the mapping of the lateral flows to WASP segments. Note, that only the sum of the constant and lateral inflows is written to the linkage file. It was not felt that it was necessary to distinguish between the two sources of lateral inflows, since only one boundary can be specified for each WASP segment (so that it could not distinguish between the two source concentrations). If a distinction is necessary, then loads from each source rather than boundary concentrations could be specified.
- Writes the initial information to the linkage file, including:
  - The number of WASP segments, flows, time step, start time, end time, and depth/velocity option. The time step specified is the hydrodynamic time step (DT) multiplied by ISKIP. The start time is the start time of the hydrodynamic simulation (in seconds) plus ISTART*DT. The end time is

the end time for the hydrodynamic simulation expressed in seconds. The depth/velocity option is set to zero, and depths and velocities written to the linkage at the end of each ISKIP interval. The depths and velocities are presently not averaged over the interval. Instead, they are values computed at the end of the ISKIP interval.

    - The flow mapping is then written to the linkage file, including all boundaries, internal and lateral flows.

  - The initial volume of each segment

Following the initial call to the subroutine, for each subsequent call

- The code checks to determine if ISKIP time steps have passed. If not the flows are accumulated
- When the number of time steps equals ISKIP, then
  - The summed flows are divided by ISKIP to determine the arithmetic average flows
  - The internal flows are recomputed from continuity (since mass balance errors will occur in the WASP model if continuity is not maintained)
  - The recomputed flows are written to the linkage file to be read by WASP. If the flows computed by RIV1 and computed by continuity differ by more than 5 percent (an arbitrarily selected upper error limit), a warning is written to the RIV1 diagnostic or error output file.
  - The volumes at the end of the ISKIP interval are written to the linkage file

Prior to writing data to the linkage file, the units of all output are converted from English to SI units, as required by WASP.

WASP Modeling Effort

The Water Quality Analysis Simulation Program version 6 (WASP6) is an enhancement of the original WASP (Di Toro et al., 1983; Connolly and Winfield, 1984; Ambrose, R.B. et al., 1988). This model helps users interpret and predict water quality responses to natural phenomena and man-made pollution for various pollution management decisions. WASP6 is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. The time-varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange are represented in the basic program.

Water quality processes are represented in special kinetic subroutines that are either chosen from a library or written by the user. WASP is structured to permit easy substitution of kinetic subroutines into the overall package to form problem-specific models. WASP6 comes with two such models -- TOXI for toxicants and EUTRO for conventional water quality. Earlier versions of WASP have been used to examine eutrophication of Tampa Bay; phosphorus loading to Lake Okeechobee; eutrophication of the Neuse River and estuary; eutrophication and PCB pollution of the Great Lakes (Thomann, 1975; Thomann et al., 1976; Thomann et al, 1979; Di Toro and Connolly, 1980), eutrophication of the Potomac Estuary (Thomann and Fitzpatrick, 1982), kepone pollution of the James River Estuary (O'Connor et al., 1983), volatile organic pollution of the Delaware Estuary (Ambrose, 1987), and heavy metal pollution of the Deep River, North Carolina (JRB, 1984). In addition to these, numerous applications are listed in Di Toro et al., 1983.

The flexibility afforded by the Water Quality Analysis Simulation Program is unique. WASP6 permits the modeler to structure one, two, and three-dimensional models; allows the specification of time-variable exchange coefficients, advective flows, waste loads and water quality boundary conditions. The eutrophication module of WASP6 was applied to the Harpeth River in this study.

Initial Model Setup

The water quality model was initially setup for 2000 and 2001, which were periods of time that were selected because of recent intensive surveys conducted by EPA. The detailed field observations were used to parameterize the both the hydrodynamic model and the water quality model. While the extensive surveys only represent a small period of time, the detailed information gathered allows for comparison of the model predictions with what was measured in the field. Because the Harpeth River has limited trend data available for the system, this intensive survey represents the most abundance of data available.

When linking WASP with a hydrodynamic model such as CE-QUAL-RIV1, the process is fairly straightforward as WASP takes on the same spatial and temporal characteristics as the hydrodynamic model. Therefore, the hydrodynamic linkage file created by the execution of CE-QUAL-RIV1 contains all the pertinent information to parameterize the model network. The only additional information that must be provided are mass loadings (boundary conditions or loads), environmental conditions, constants and kinetics. As described in the “WASP Linkage Description and Input Requirements” section in this report, linkage routines were developed between the CE-QUAL-RIV1 hydrodynamic model and WASP. As a result, all hydraulic information from the CE-QUAL-RIV1 model during WY92 – WY01 is transferred to WASP including the upstream boundary flows, lateral flows, velocities, depths and segment volumes. As a result of the linkage between the models, the segmentation of WASP is consistent with the segmentation of the CE-QUAL-RIV1 model. Therefore, the tributary inflows to the WASP model are assigned to segments consistent with tributary inflow locations of the CE-QUAL-RIV1 model. For the application of CE-QUAL-RIV1, each tributary inflow was applied to the nearest RIV1 cross-section. Tributary flows to the WASP model were then distributed to segments upstream and downstream from the cross-section locations. The assignment to the tributary inflows to the WASP segments is shown in the Table 19.

Table 19. Assignment of Tributary flows to WASP segments

Tributary	LSPC watershed ID#	RIV1 cross-section	River Mile	WASP segment	Weight	WASP segment	Weight
Upstream boundary	52	1	88.10	1	1.0		
Spencer Creek	34	8	85.55	7	0.5	8	0.5
Urban streams	35	8	85.55	7	0.5	8	0.5
Lynnwood Branch	31	22	80.15	21	0.5	22	0.5
West Harpeth River	30	25	78.85	24	0.5	25	0.5
Murray Branch	19	37	73.65	36	0.5	37	0.5
Little Harpeth River	18	63	62.40	62	0.467	63	0.533
Newsome/Beech/Trace Creeks	14	91	50.13	90	0.5	91	0.5
South Harpeth River	15	105	44.23	104	0.5	105	0.5
Brush Creek	17	107	43.45	106	0.5	107	0.5
Hannah Branch	10	122	37.50	121	0.5	122	0.5
Turnbull Creek	11	128	35.10	127	0.5	128	0.5
Unnamed tribs	53	133	33.15	132	0.5	133	0.5
Downstream boundary	-	135	32.40	134	1.0		

The LSPC watershed model provided hydrographs (flow) for the major tributaries entering the Harpeth River, the hydrographs were incorporated into the hydrodynamic model, and the loads associated with these flows must be accounted for in the water quality model. LSPC provides WASP a time series of daily average concentrations of ammonia, nitrate, orthophosphate, organic nitrogen, organic phosphorus and BOD for each of the tributaries. LSPC has calculated the pollutagraph and hydrograph to be used by WASP for a 10-year period (i.e., WY92 – WY01).

In addition to the tributary inflows, loads were input to the WASP model from four NPDES permitted dischargers (Table 20). Flows from the Franklin STP had been included in the CE-QUAL-RIV1 model. The flows from the other three facilities (i.e., the Lynnwood STP, the Cartwright Creek Utility District STP, and the Harpeth Valley Utility District STP) were not included in the CE-QUAL-RIV1 model because of their relative insignificance concerning the contribution to the flow in the Harpeth River. A 10-year record of loads from each of these facilities was provided to WASP as boundary conditions to WASP segments described in the table below. These loads were determined from flows and pollutant concentrations from: 1) data available in EPA's Permits Compliance System (PCS) database; 2) monthly report data provided by TDEC; and 3) effluent data provided to EPA by the permittees.

Table 20. Assignment of point source loads to WASP segments

NPDES permitted facility	Location of discharge	WASP segment	Weight	WASP segment	Weight
Franklin STP	RM 85.3	6	0.5	7	0.5
Lynnwood STP	RM 77.9	23	1.0	-	-
Cartwright Cr Utility STP	RM 68.8	49	1.0	-	-
* Harpeth Valley Utility STP	RM 57.8	73	1.0	-	-

* The Harpeth Valley Utility STP ceased discharging to the Harpeth River beyond January 2001.

The WASP model was parameterized using the available data collected during WY92 – WY01. The available data during this 10-year period primarily consists of the data collected by EPA during the Harpeth River watershed studies conducted in 2000 and 2001. For this reason the model is initially setup for 2000/2001.

Model Parameterization

The WASP model was parameterized to predicted the dissolved oxygen concentrations as function of environmental, hydraulic and loading conditions. Equation 1 illustrates the processes considered by the water quality in predicted dissolved oxygen.

Equation 1. Dissolved Oxygen Representation in Harpeth River Model

$$DO = \underbrace{[\mathrm{Re}\,aeration + \mathrm{Pr}\,oductivity]}_{SOURCES} - \underbrace{[BOD\ Decay + SOD + \mathrm{Re}\,spiration + Nitrification]}_{SINKS}$$

Reaeration

Reaeration is the process in which oxygen is exchanged from the atmosphere to the water column. When modeling dissolved oxygen it is important to account for reaeration, but determining the rate at which this exchange occurs is critical. It is becoming a more wide spread practice of measuring site-specific reaeration rates. Using site-specific data in the development of TMDLs maybe be problematic in that the critical condition in which the TMDL is being developed to may not be represented by conditions in which the site-specific data was collected. The site-specific data certainly would provide a reality check for the reaeration rate calculated for the TMDL determination.

WASP calculates reaeration as a function of water depth and velocity. In the case of the Harpeth River, water velocities and depths are provided to WASP via the hydrodynamic linkage file from CE-QUAL-RIV1. The effective reaeration rates vary in space and time.

Productivity/Respiration

Algal, macrophyte and periphyton productivity and respiration can play an important role in the overall dissolved oxygen budget. Ultimately, the control of algae, macrophytes and periphyton can be used in achieving water quality objectives for a waterbody.

Periphyton in the Harpeth River has dramatic influence on diurnal swings in dissolved oxygen. While there was not sufficient data to dynamic simulate periphyton, the impact is encompassed in the WASP model by using a net productivity approach. This approach assumes a standing biomass (not changing with respect to time), a net growth and death rate are supplied to the model. These values are adjusted until the observed diurnal swing is predicted by the model (see Figure 45). While the model does not predict the periphyton concentrations, the impact on dissolved oxygen is considered as a function of environmental conditions (light and temperature) and available nutrient concentrations.

BOD Decay

The carbonaceous biochemical oxygen demand (CBOD) inputs to the model were established using information from the August 2000 and the April 2001 studies (see Table 5 and Table 6) as well as NPDES discharge information available in the permittees' monthly operating reports.

The BOD loadings for the tributaries were simulated using LSPC. The loadings from LSPC were considered ultimate BOD and were entered directly into WASP.

Long term BOD analysis performed by EPA was used to determine the range of the BOD decay rate in the water quality model. This BOD decay rate is universal to the model network; the rate is adjusted as a function of environmental conditions.

Sediment Oxygen Demand

The decomposition of organic material in benthic sediment can have profound effects on the concentrations of oxygen in the overlying waters. The decomposition of organic material results in the exertion of an oxygen demand at the sediment-water interface. As a result, the aerial fluxes from the sediment can be substantial oxygen sinks to the overlying water column. The number of in-situ sediment oxygen demand (SOD) measurements throughout the mainstem of the Harpeth River was extremely limited, due to poor conditions for deployment of chambers to measure SOD. However, SOD estimates were made by EPA through the use of measured community respiration rates. These SOD estimates were used in the parameterization of the water quality model.

WASP Kinetic Constants

Table 21 provides a list of the kinetic constants used in the 2000-2001 model simulation.

Table 21. Kinetic Constants for Water Quality Model

Kinetic Constant	Value
Nitrification Rate @20c	0.4
Nitrification Temperature Coefficient	1.07
Half Saturation: Nitrification Oxygen Limit	2
Nitrification Rate @20c	0.4
Nitrification Temperature Coefficient	1.07
Half Saturation: Nitrification Oxygen Limit	2
Phytoplankton Maximum Growth Rate @20c	2
Phytoplankton Growth Temperature Coefficient	1.07
Phytoplankton Light Formulation Switch (1=DiToro, 2=Smith)	1
Phytoplankton Maximum Quantum Yield Constant	500
Phytoplankton Carbon::Chlorophyll Ratio	60
Phytoplankton Optimal Light Saturation	320
Phytoplankton Half-Saturation Constant for Nitrogen	0.05
Phytoplankton Half-Saturation Constant for Phosphorus	0.05
Phytoplankton Endogenous Respiration Rate @20c	0.8
Phytoplankton Respiration Temperature Coefficient	1.08
Phytoplankton Carbon::Phosphorus Ratio	0.24
Phytoplankton Carbon:: Nitrogen Ratio	0.43
Phytoplankton Half-Sat. for Recycle of Nitrogen and Phosphorus	1
BOD Decay Rate @20c	0.07
BOD Decay Rate Temperature Correction	1.047
BOD Half Saturation Oxygen Limit	0.5
Dissolved Organic Nitrogen Mineralization Rate @20c	0.2
Dissolved Organic Nitrogen Mineralization Temperature Coefficient	1.08
Fraction of Phytoplankton Death Recycled to Organic Nitrogen	1
Mineralization Rate of Dissolved Organic Phosphorus @20c	0.1
Dissolved Organic Phosphorus Mineralization Temperature Coefficient	1.08
Fraction of Phytoplankton Death Recycled to Organic Phosphorus	1

Environmental Conditions

The primary environmental conditions that were provided in the water quality model are water temperature and solar radiation. Water temperature influences the rate constants in the model. Virtually all of the decay terms in the model are attenuated by temperature. Solar radiation directly impacts the productivity of the system. Figure 42 and Figure 43 illustrate the time series of water temperature and solar radiation.

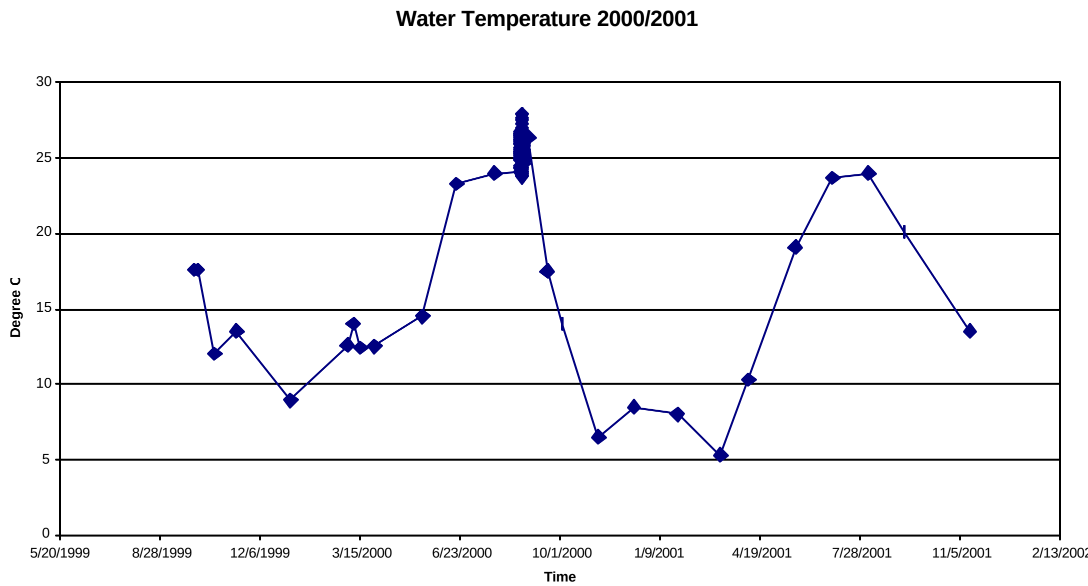


Figure 42. Water Temperature for 2000

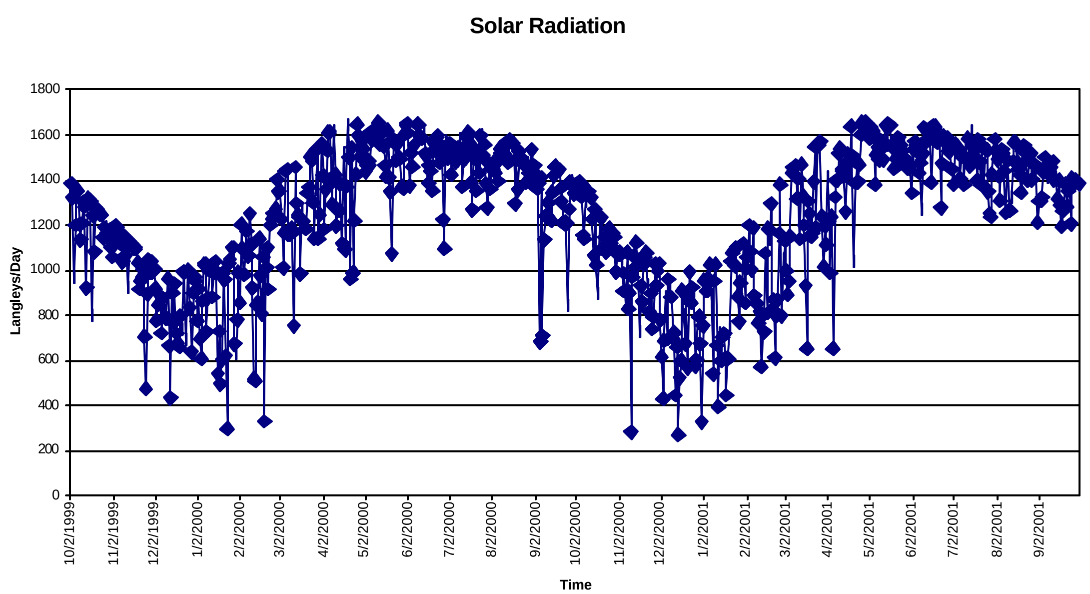


Figure 43. Solar Radiation 2000/2001

Calibration Objectives

The calibration objectives used to parameterize the model to best represent the observed gradients in the Harpeth River. Because of limited continuous time series data the model was parameterized using all available information gained from the intensive surveys. There exists several time periods within 2000 and

2001 when diurnal characteristics of the Harpeth River were measured. Given the limited information to parameterize the model to actually simulate the productivity in the system, a net productivity and respiration approach was taken to simulate diurnal variations. The judgment of fit of the calibration was qualitative (best professional judgment of model fit to observed data) because there were not enough observations to make a statistical comparison.

The model was initially calibrated to the 2000 observed data. Figure 44 shows how well the model predictions compared with all of the observed dissolved oxygen data for the Harpeth River. It should be pointed out that the upstream boundary at river mile 88.1, for the period of time where observed data exists, shows a fairly substantial diurnal variation. The purpose of the calibration was not to simulate completely the diurnal variations, but to insure the model was capturing the trends observed in the Harpeth River.

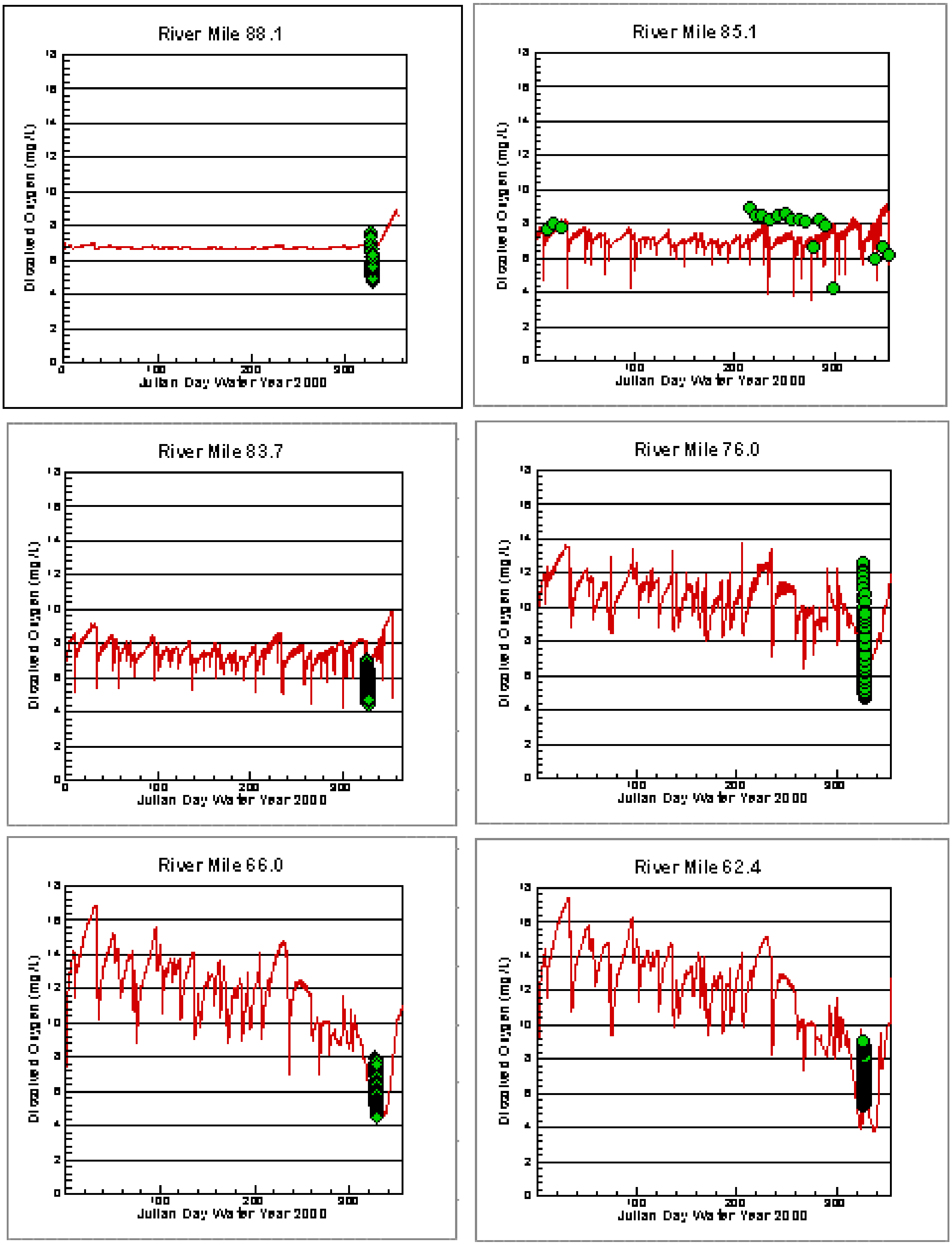


Figure 44. Dissolved Oxygen Predicted vs. Observed all Stations for 2000

Figure 45 illustrates the water quality models ability to simulate diurnal variations in dissolved oxygen.

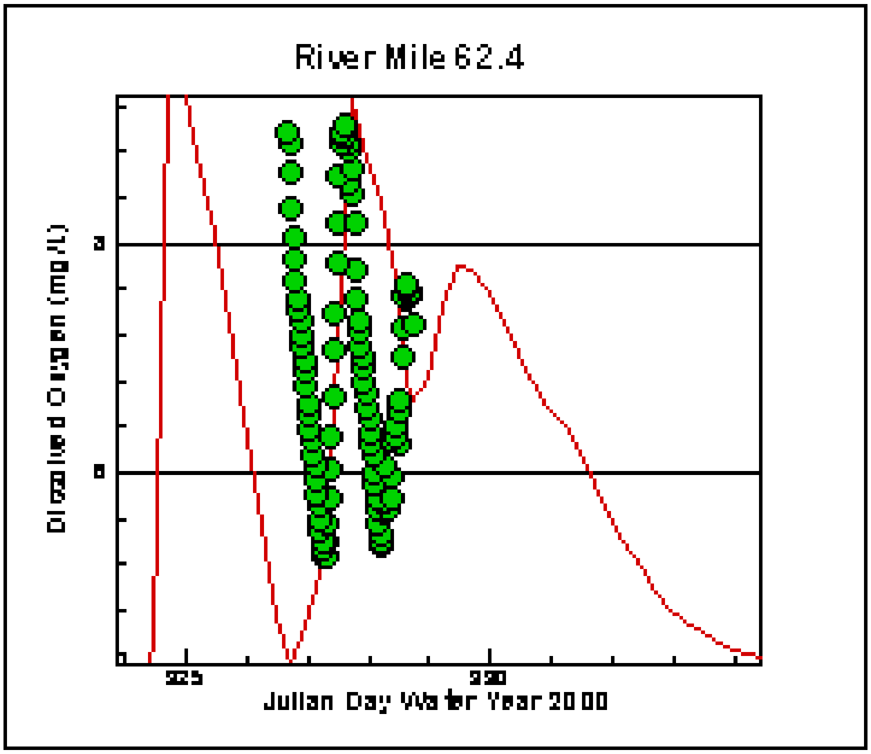


Figure 45. Diurnal Dissolved Oxygen Variation

In addition to dissolved oxygen data, additional water chemistry data was available for 2000. When comparing the predicted instream ultimate BOD and ammonia concentrations at the various stations where water chemistry data was available, the agreement with the water quality model is quite good. The instream ultimate BOD and ammonia concentrations are a function of the loadings provided by the watershed model and the kinetic constants in the water quality model.

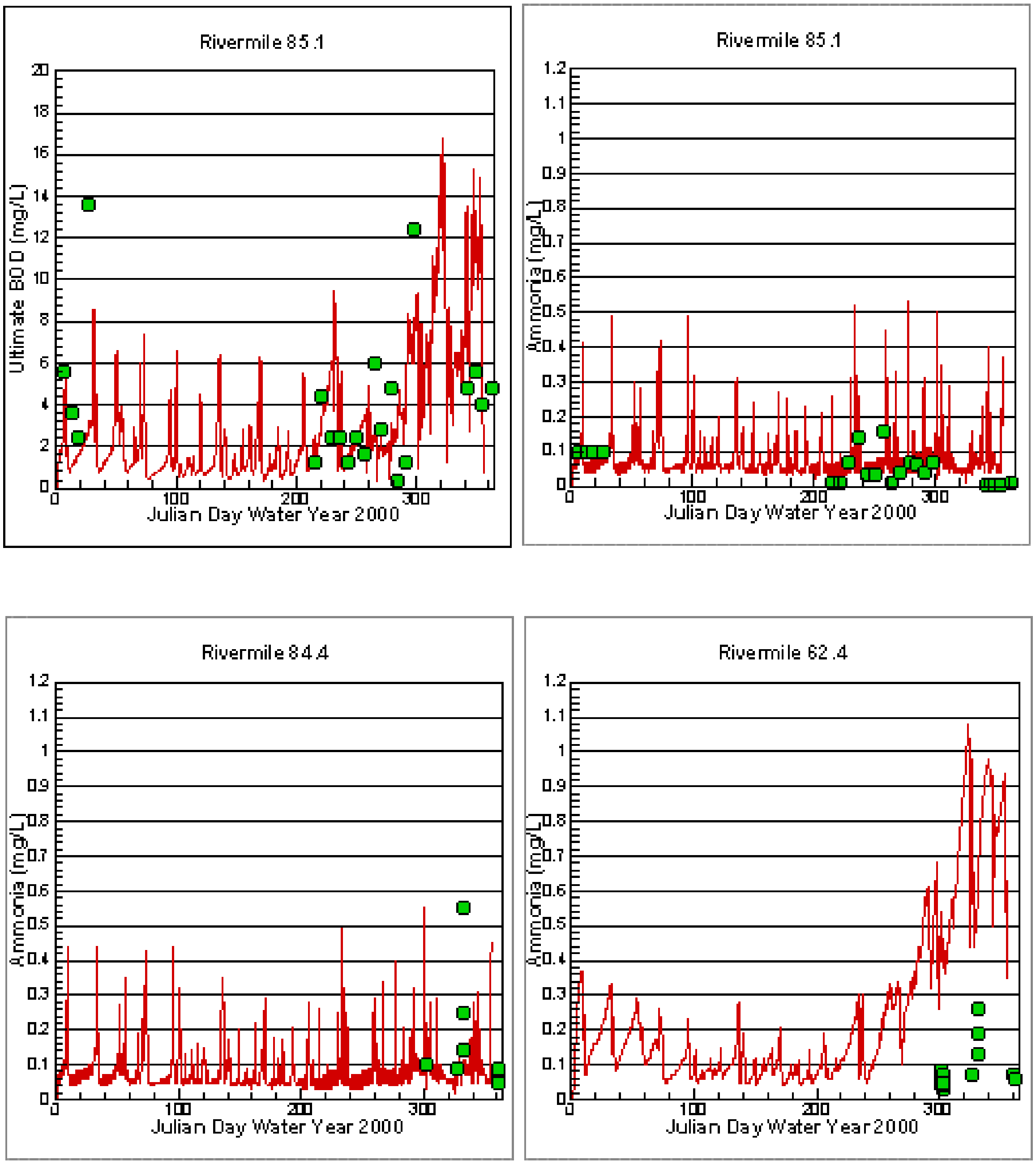


Figure 46. Water Chemistry Data Observed vs. Predicted 2000

Upon completion of the initial calibration to 2000, the water quality model was verified to the 2001 water year, where intense monitoring data was available. The model was recalibrated for the 2001 conditions, and the results of the dissolved oxygen calibration are provided in Figure 47. Again the purpose of the calibration is for the model to predict the dynamic changes in dissolved oxygen, but not trying to encompass the diurnal variations. Once the model was re-calibrated for 2001, the same kinetic constants were used in the 2000 predictions.

Figure 48 illustrates how well the model did for water chemistry. While the model did not do as well for 2001 as 2000, the model does indicate that the loadings are within reason for the time period. The model does tend to under predict ultimate BOD towards the end of the year, this indicates that maybe the watershed model is under predicting the load, or that the f-ratio used to convert BOD 5 day to ultimate may not have been appropriate.

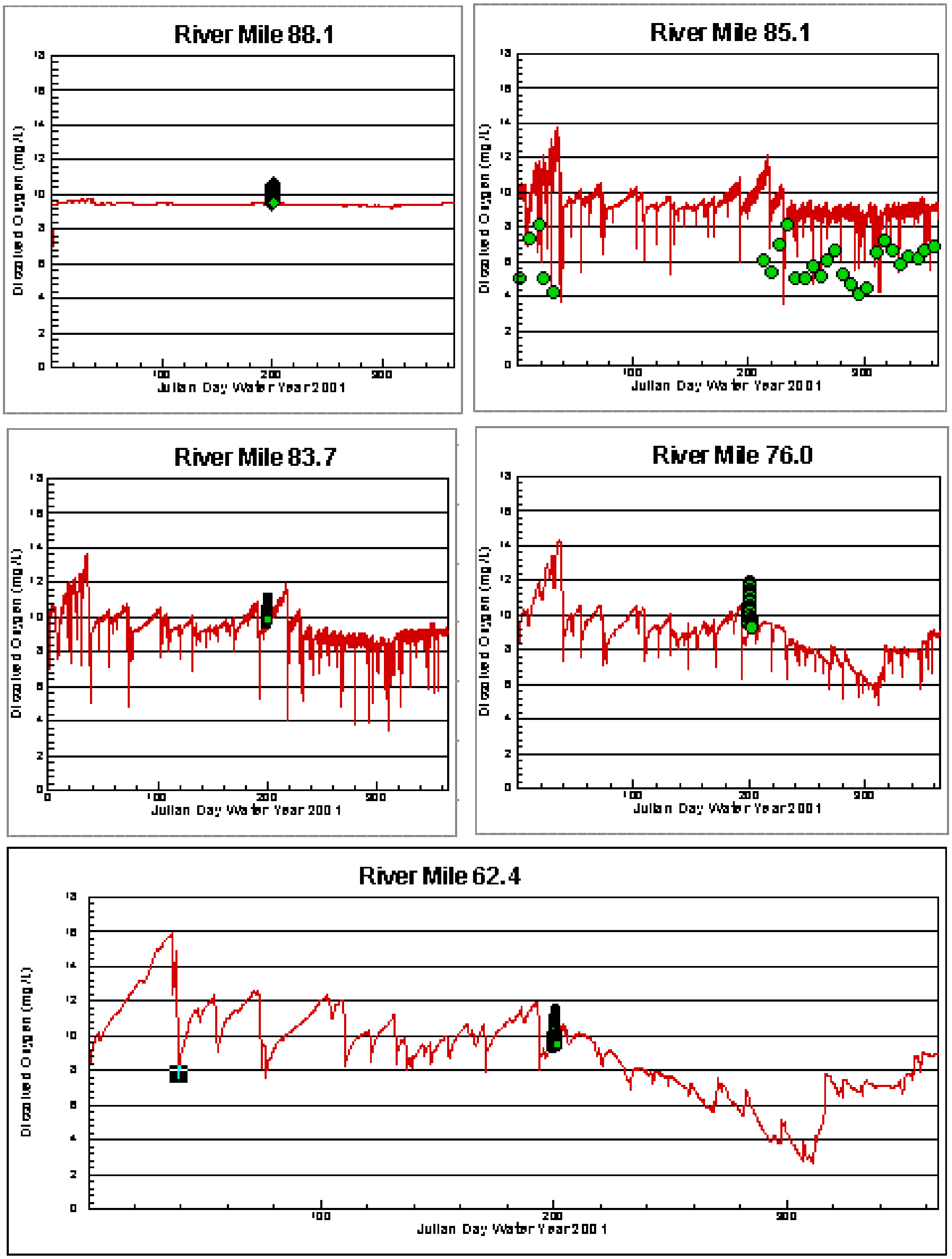
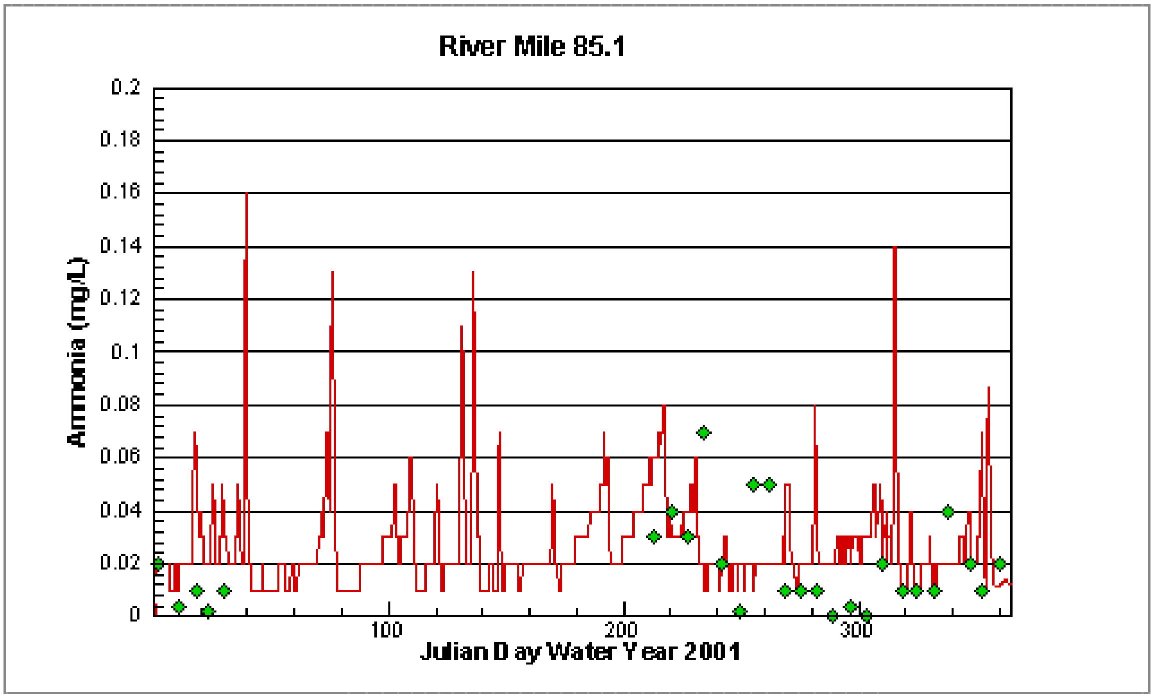


Figure 47. Dissolved Oxygen Predicted vs. Observed all Stations for 2001



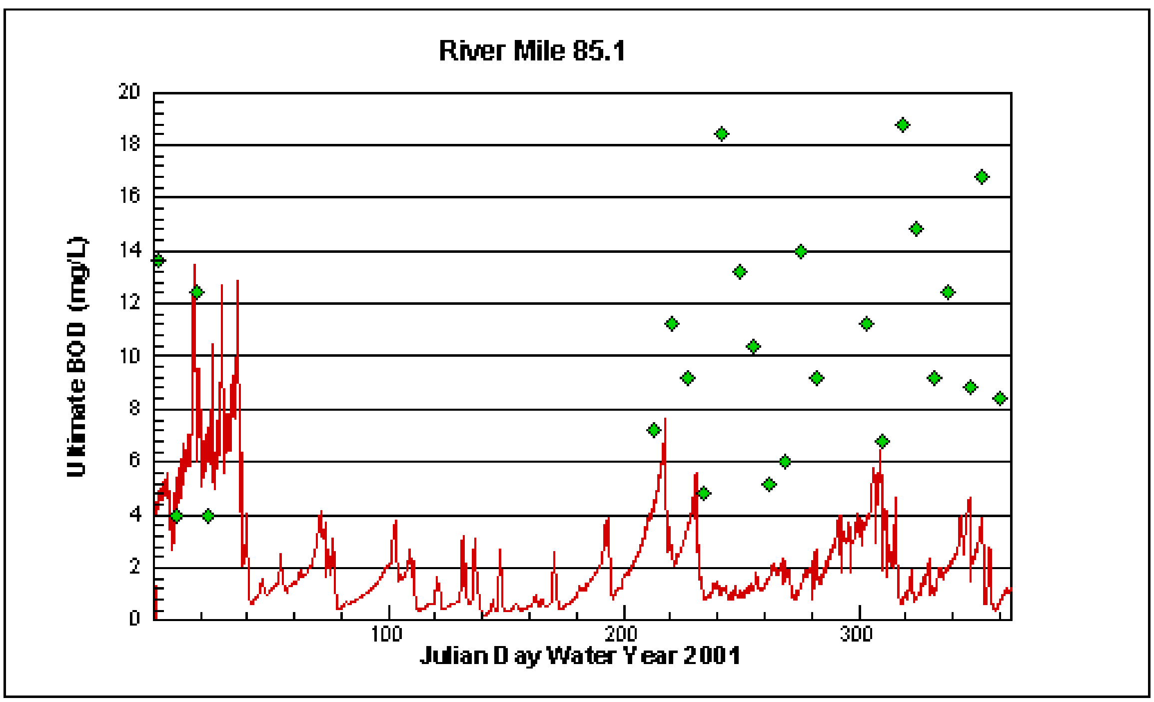


Figure 48. Water Chemistry Data Observed vs. Predicted 2001

Relative Impacts of Loadings on Water Quality Modeling

The development and application of these watershed modeling tools (LSPC, CE-QUAL-RIV1, LSPC) to the Harpeth River system will be provide a valuable method for evaluating watershed management strategies. The ability to accurately predict the dynamic changes in flow within in this system gives greater confidence to the application of the water quality model. Accurately predicting travel times is an important step in predicting water quality. Furthermore, the watershed model provides a good estimate of the loadings associated with rainfall events.

While there is not enough time series data to fully calibrate the model under all conditions (load, flow, seasonality), the model will be a useful tool to evaluate the relative impact of management strategies for future scenarios. The model is also capable of looking for critical periods of time, which should be considered when developing a TMDL. Figure 49 illustrates a critical time period simulated by the model, while there exists no data to substantiate this condition; the model clearly shows large dissolved oxygen sag during a summer month. This critical condition is caused by an extremely low flow at the upstream boundary; the river is effluent dominant in the upper portion.

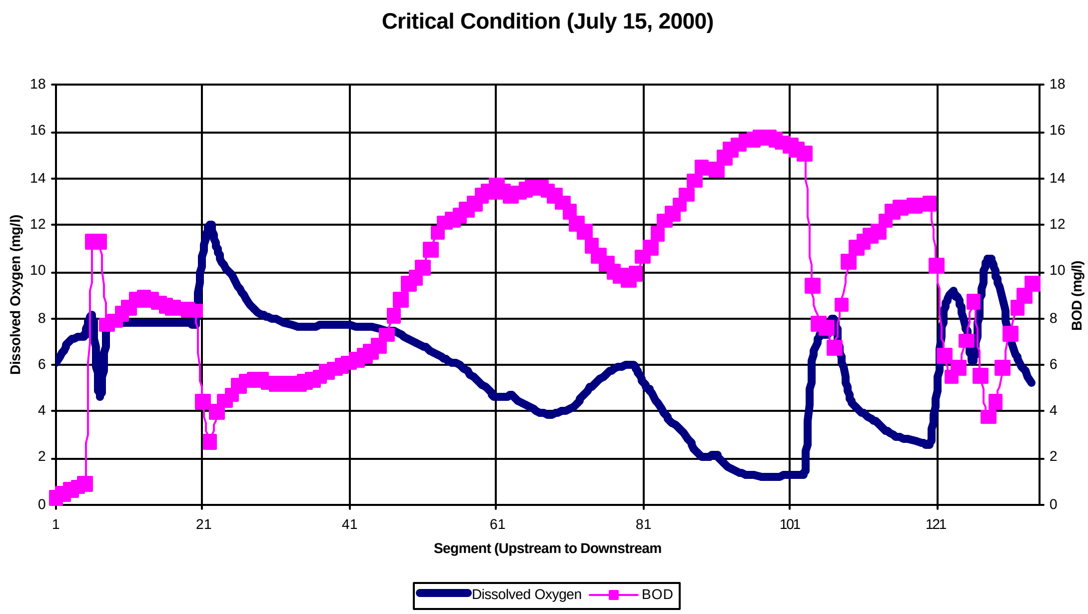


Figure 49. Critical Condition Analysis

QUAL2E Modeling Effort

The Enhanced Stream Water Quality Model (QUAL2E) is a comprehensive and versatile one-dimensional, steady-state stream water quality model. It can simulate up to 15 water quality constituents in any combination desired by the user. The model is applicable to dendritic streams that are well mixed. It assumes that the major transport mechanisms, advection and dispersion, are significant only along the main direction of flow (longitudinal access of the stream). It allows for multiple waste discharges, withdrawals, tributary flows, and incremental inflow and outflow (Brown and Barnwell, 1987).

The QUAL2E model was applied to the upper Harpeth River watershed from the headwaters to RM89.2 (Figure 50). The intention of the model application was to make best efforts to simulate the processes that impact dissolved oxygen concentrations in the segments of the upper Harpeth River system during low-flow conditions. As stated earlier in the report, there are significant limitations of applying a steady-state riverine model to this system. However, if used responsibly, QUAL2E can be used as an appropriate tool for the TMDL development process for the upper part of the watershed.

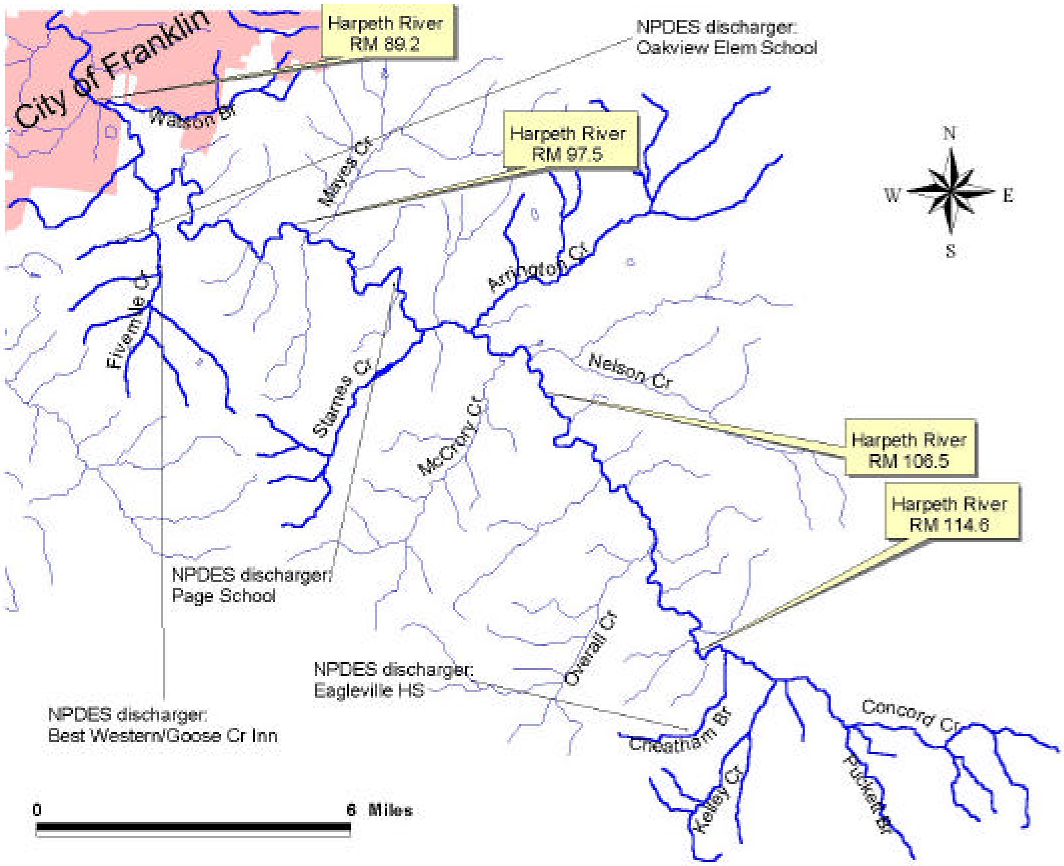


Figure 50. Upper Harpeth River Watershed

QUAL2E Reach Representation

The headwaters of the Harpeth River originate from Concord Creek, Puckett Branch, and Kelley Creek. These headwater streams do not receive wastewater discharges from any point sources and they are all located in an area dominated by an agriculture landuse. Therefore these streams are represented, or lumped, as a single headwater reach in QUAL2E. Cheatham Branch is also a headwater stream in an area dominated by an agricultural landuse. However, this stream receives a minor discharge of treated wastewater from Eagleville School and it is included in the model as an individual reach.

The upper Harpeth River receives flows from several other tributaries (Figure 50). It was decided that the tributaries that were impaired from "Organic enrichment/DO" on TDEC's 1998 §303(d) lst would be included as individual reaches in the QUAL2E model (i.e., Arrington Creek, Starnes Creek, Fivemile

Creek, and Watson Branch). Although there is no evidence that any of these tributaries are impaired from low levels of dissolved oxygen, EPA included them in the model in order meet a requirement of a Settlement Agreement. In addition, Fivemile Creek and an unnamed tributary to Fivemile Creek receive minor discharges of treated wastewater respectively from the Best Western/Goosecreek Inn and Oakview Elementary School. These waters were included as individual reaches in the model. The other significant tributaries to the upper Harpeth River (i.e., Overall Creek, Nelson Creek, McCrory Creek, and Mayes Creek) are included in the QUAL2E model as point sources. In addition, Page Middle School discharges treated wastewater to the Harpeth River at RM 101.9.

A low-head dam and a drinking water intake from the City of Franklin are located in the proximity of RM89.2. During EPA's August 2000 water quality study, a 150-meter segment of the Harpeth River channel located immediately downstream from the low-head dam was observed to be dry. EPA did not attempt to describe or represent any of these characteristics as part of the QUAL2E model. However, considering that observed DO levels increase and observed BOD levels decrease in the downstream direction in the upper portion of the Harpeth River, EPA and TDEC are confident that water quality standards in the vicinity of RM89.2 will be met as long as water quality standards are met upstream from this point.

The upper Harpeth River watershed is represented as 15 reaches in the QUAL2E model (Table 22). Considering the total length of the system that is modeled as well as the spatial resolution of the available data, the length of each computational element (i.e., Delta X) was selected to be 0.5 miles. Although the QUAL2E model ends at RM88.6, one should be mindful that there are many complex hydraulic processes in the vicinity of RM89.2 that are not simulated (e.g., low-head dam effects on velocity, effects of drinking water intake on flow, the dry portion of the channel).

Table 22. Reaches represented by QUAL2E

Reach number	QUAL2E Reach name	Beginning RM	Ending RM	Headwater reach ( )	Delta X (mile)
1	HR123.1-115.6	123.1	115.6		0.5
2	Cheatham Br	2.5	0		0.5
3	HR115.6-111.1	115.6	111.1		0.5
4	HR111.1-103.6	111.1	103.6		0.5
5	Arrington Cr	8.5	0		0.5
6	HR103.6-102.6	103.6	102.6		0.5
7	Starnes Cr	5.5	0		0.5
8	HR102.6-97.6	102.6	97.6		0.5
9	HR97.6-91.6	97.6	91.6		0.5
10	Fivemile Cr 1	5.0	1.0		0.5
11	UT to Fivemile	1.5	0		0.5
12	Fivemile Cr 2	1.0	0		0.5
13	HR91.6-89.6	91.6	89.6		0.5
14	Watson Br	5.0	0		0.5
15	HR89.6-88.6	89.6	88.6		0.5

Hydraulic Representation

During the August 2000 water quality study of the Harpeth River, the flows in the upper portion of the Harpeth River were extremely low (i.e., 0.02 – 0.03 cfs). In addition, the velocities were also measured to be very low (i.e., approximately 0.03 feet per second (fps)). Using the principle of continuity, the cross-sectional area throughout the upper river during these conditions is known to be on the order of 1 ft^2. Considering the data collected during the surveying of cross-sections as well as the cross-section information collected during the gaging of flows, the width:depth ratios were estimated to range between 10 and 100.

Although the tributary flows in the watershed are extremely low during low-flow conditions, an attempt was made to estimate these flows. The primary factors considered in appropriately distributing these flows included: 1) the relative size of the respective sub-watershed drainage areas; 2) the distribution of tributary flows that were measured during the April 2001 study, when flows were significantly greater; and 3) the effluent flowrates measured from the NPDES dischargers during August 2000. Considering that tributary velocities and depths were not measured during low-flow conditions, an assumption was made that the tributary velocities and depths would have generally been lower than those in the mainstem of the Harpeth River. The velocities in the tributaries were assumed to be 0.01-0.02 fps and the depths were set at levels that would ensure width:depth ratios within the range of 10 to 100.

The estimated velocities and depths were entered directly into QUAL2E (Table 23). That is, they were not entered as a function of flow.

Table 23. Flows and velocities entered into QUAL2E

Reach number	Reach name	Velocity (fps)	Depth (feet)
1	HR123.1-115.6	0.03	0.08
2	Cheatham Br	0.01	0.05
3	HR115.6-111.1	0.034	0.1
4	HR111.1-103.6	0.034	0.1
5	Arrington Cr	0.01	0.05
6	HR103.6-102.6	0.033	0.1
7	Starnes Cr	0.01	0.03
8	HR102.6-97.6	0.032	0.1
9	HR97.6-91.6	0.031	0.1
10	Fivemile Cr 1	0.01	0.08
11	UT to Fivemile	0.02	0.04
12	Fivemile Cr 2	0.02	0.1
13	HR91.6-89.6	0.025	0.2
14	Watson Br	0.01	0.03
15	HR89.6-88.6	0.02	0.2

The flows for all of the headwater reaches of the QUAL2E model are input as incremental inflow, as opposed to being entered at the headwaters. This decision was made in order to allow an incremental loading of oxygen consuming loads along a reach. The boundary flows from tributaries and NPDES dischargers were entered as point sources. All of these boundary flows are described in Table 24 and Table 25.

Table 24. Incremental Flow Inputs

Reach number	Reach name	Incremental Flow (cfs)
1	HR123.1-115.6	0.017963
2	Cheatham Br	0.001289
5	Arrington Cr	0.002147
7	Starnes Cr	0.000699
10	Fivemile Cr 1	0.001085
11	UT to Fivemile	0.000128
12	Fivemile Cr 2	0.000064
14	Watson Br	0.000601

Table 25. Flows from tributaries and NPDES dischargers

Reach No.	Element No.	Point Source/ Tributary	Flow (cfs)
2	2	Eagleville School	0.000748
3	9	Overall Creek	0.001178
4	11	Nelson Creek	0.001448
4	13	McCrory Creek	0.001350
8	2	Page Middle School	0.000294
8	10	Mayes Creek	0.003178
10	6	Best Western-Goosecreek Inn	0.005281
11	2	Oakview Elementary	0.002561

Temperature

Concerning this application of QUAL2E, there was no benefit to simulating temperature. The temperatures were described to the model through initial conditions and boundary conditions. Although this model was run in steady-state mode, QUAL2E uses the initial temperature conditions to set the values of the temperature-dependent rate constants. The temperatures input to the model ranged between 76.3 – 77.7 degrees Fahrenheit (see Appendix A for more details) that yielded instream temperatures consistent with the average temperatures measured during the August 2000 study. In addition, the default temperature-correction factors in QUAL2E used to adjust decay and settling rates, reaeration, and SOD uptake were not changed.

Carbonaceous Biochemical Oxygen Demand

The carbonaceous biochemical oxygen demand (CBOD) inputs to the model were established using information from the August 2000 and the April 2001 studies (Table 5 and Table 6) as well as NPDES discharge information available in the permittees' monthly operating reports from August 2000. The relative differences in CBOD concentrations measured in April 2001 from the tributaries to the Harpeth River were used to parameterize the tributary CBOD concentrations. In the absence of available effluent long-term CBOD data for the NPDES dischargers in the upper Harpeth River watershed, 5-day CBOD ($CBOD_5$) effluent concentrations were converted to ultimate CBOD (UCBOD) concentrations using an f-ratio value of 3.23, which is consistent with f-ratios associated with effluent receiving secondary treatment (Chapra, 1997).

The attempt to calibrate the CBOD in the Harpeth River was conducted through the adjustment of the instream decay rates as well as the tributary concentrations input to QUAL2E. When the concentrations input to the model were adjusted, however, the relative contributions from each tributary remained constant. The measured bottle CBOD decay rates sampled from the Harpeth River were generally low (i.e., as low as 0.05 day^{-1}). A CBOD deoxygenation rate of 0.02 day^{-1} was applied to the entire upper Harpeth River system and yielded a reasonable fit between observed and predicted CBOD concentrations (Figure 51).

Table 26. UCBOD concentrations for the incremental flow

Reach number	Reach name	UCBOD (mg/l)
1	HR123.1-115.6	10
2	Cheatham Br	5
5	Arrington Cr	5.5
7	Starnes Cr	9.5
10	Fivemile Cr 1	2
11	UT to Fivemile	2
12	Fivemile Cr 2	2
14	Watson Br	8

Table 27. UCBOD concentrations for tributaries and NPDES dischargers

Point Source/ Tributary	UCBOD (mg/l)
Eagleville School	6.2
Overall Creek	5
Nelson Creek	5.1
McCrory Creek	4.2
Page Middle School	19.4
Mayes Creek	4
Best Western-Goosecreek Inn	9.7
Oakview Elementary	9.7

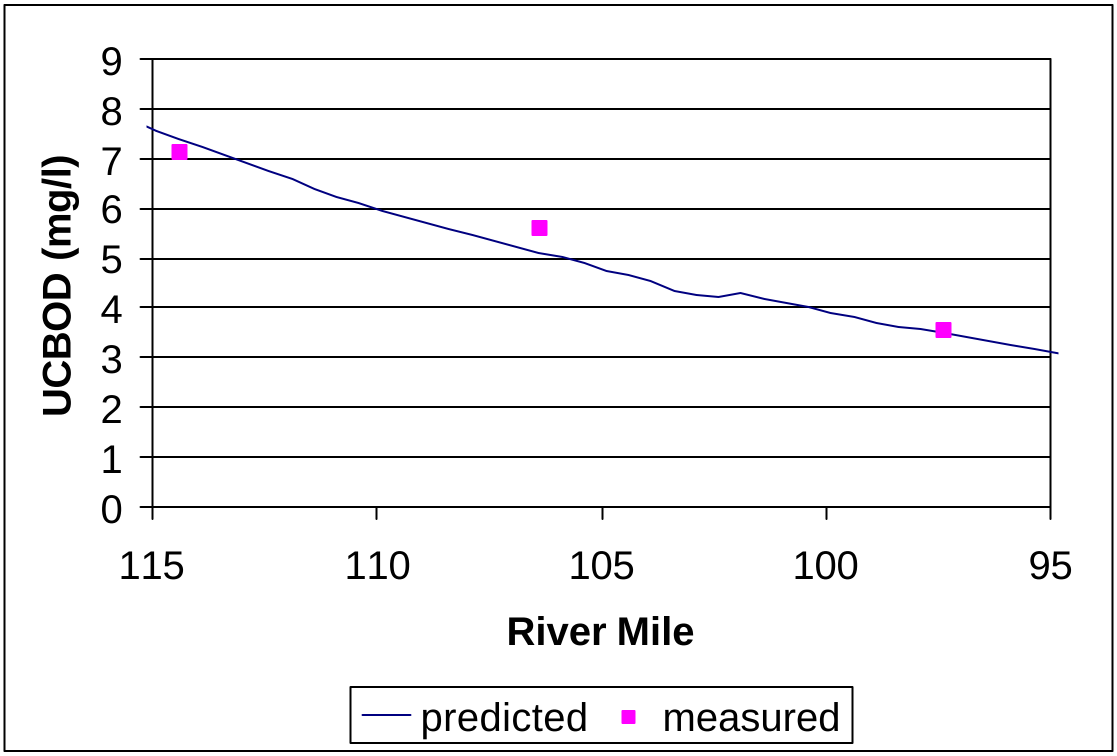


Figure 51. Deoxygenation of UCBOD: predicted and observed concentrations

Nitrogenous Biochemical Oxygen Demand

The nitrogen levels measured in the water column of the upper Harpeth River were generally low as shown in Table 5 and Table 6. As a result, the impact nitrogen had on dissolved oxygen levels was minimal (see model output in Appendix A for details). However, EPA went forward in attempting to calibrate the nitrification processes of the nitrogen cycle. The process was very similar to that used for the attempt to calibrate CBOD.

NH3-N concentrations were the only effluent nutrient data available from the NPDES discharges in the upper Harpeth River watershed. Assumptions were therefore made concerning the remainder of the other components of nitrogen in the effluent as shown in Table 29.

The relative differences in nitrogen concentrations measured in April 2001 from the tributaries to the Harpeth River were used to parameterize the tributary nitrogen concentrations. The attempt to calibrate the nitrification processes in the Harpeth River was conducted through the adjustment of the instream decay rates as well as the tributary loads input to QUAL2E. When the loads input to the model were adjusted, however, the relative contributions from each tributary remained constant. Figure 52 shows the comparisons of observed organic nitrogen with predicted organic nitrogen using the loading information from Table 28 and Table 29 and applying an organic nitrogen hydrolysis rate of 0.02 day^{-1}. Figure 53 shows the comparisons of observed ammonia nitrogen with predicted ammonia nitrogen using the loading information from Table 28 and Table 29 and applying an ammonia oxidation rate of 0.2 day^{-1}.

Table 28. Nitrogen concentrations for the incremental flow

Reach number	Reach name	Organic N (mg/l)	NH_3-N (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)
1	HR123.1-115.6	0.9	0.1	0.01	0.09
2	Cheatham Br	0.9	0.1	0.01	0.09
5	Arrington Cr	0.2	0.1	0.01	0.09
7	Starnes Cr	0.2	0.1	0.01	0.09
10	Fivemile Cr 1	0.2	0.1	0.01	0.09
11	UT to Fivemile	0.2	0.1	0.01	0.09
12	Fivemile Cr 2	0.2	0.1	0.01	0.09
14	Watson Br	0.2	0.1	0.01	0.09

Table 29. Nitrogen concentrations for tributaries and NPDES discharges

Point Source/ Tributary	Organic N (mg/l)	NH_3-N (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)
Eagleville School	5	0.95	0.5	4.5
Overall Creek	0.2	0.1	0.01	0.1
Nelson Creek	0.2	0.1	0.01	0.1
McCrory Creek	0.2	0.1	0.01	0.1
Page Middle School	10	5	1	90
Mayes Creek	0.1	0.1	0.01	0.1
Best Western-Goosecreek Inn	5	0.37	0.5	4.5
Oakview Elementary	5	0.12	0.5	4.5

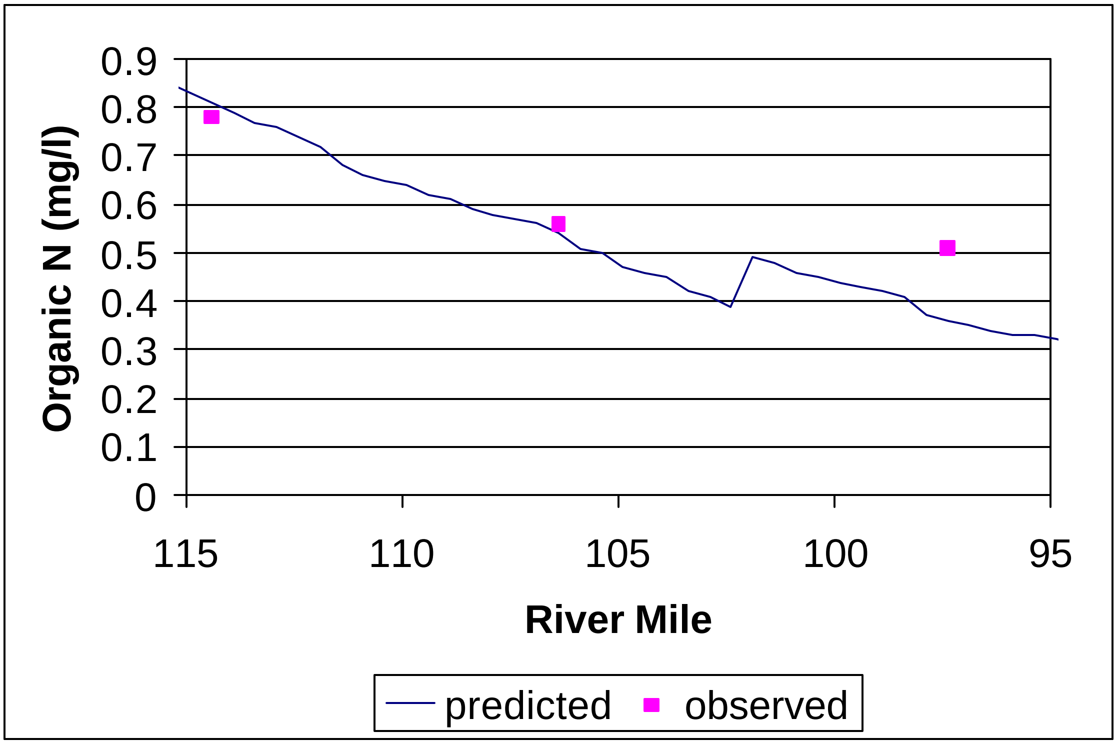


Figure 52. Hydrolysis of organic nitrogen: predicted and observed concentrations

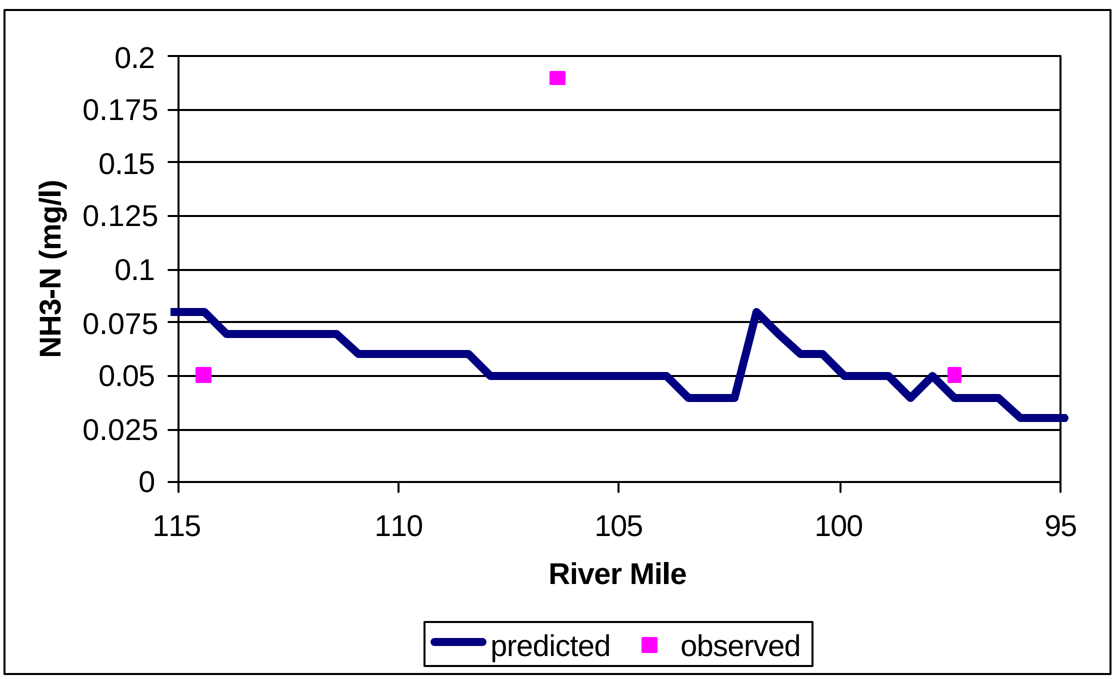


Figure 53. Oxidation of ammonia nitrogen: predicted and observed concentrations

Consideration of Algae

Simulating algae and the uptake of nutrients were examined as part of the QUAL2E modeling effort. The measured levels of nutrients and chlorophyll a concentrations in the water column of the upper Harpeth River are very low, and as mentioned earlier in the report, periphyton is the dominant form of algae in this system. Considering the lack of quantitative periphyton data as well as QUAL2E's limitations in modeling the periphyton form of algae, EPA did not attempt to include periphyton as part of the modeling effort.

Using the available water column data, EPA conducted runs of the QUALE model that included the algae and nutrient cycling algorithms. As part of a sensitivity analysis, boundary concentrations of chlorophyll a and nutrients greater than those measured in the field were entered as inputs to the model. However, the net effect of algal productivity and respiration on dissolved oxygen concentrations was negligible. Therefore, EPA did not attempt to calibrate the algae or phosphorus cycling.

Sediment Oxygen Demand

Although sediment oxygen demand (SOD) was not measured directly in the upper part of the Harpeth River, it can be calculated using community metabolism data. Through post-processing of the field data collected by EPA, the net substrate respiration during August 2000 was estimated to be 10.32 g-O_2/m^3/day, 6.56 g-O_2/m^3/day, and 5.96 g-O_2/m^3/day respectively for the Harpeth River stations at RM114.6, RM106.5, and RM97.5 (Koenig, 2001). By applying these values to the depths estimated for reaches 3, 4, and 9 (Table 23), the resulting calculated SOD values are shown in Table 30. Table 30 also shows SOD values on the mainstem of the Harpeth River that were interpolated or extrapolated from the calculated SOD values.

It should be noted that the SOD in the headwater reaches (i.e., reaches 1 and 3) was assumed to be higher than the SOD in the downstream reaches, considering the high levels of CBOD originating from this part of the watershed. Although tributary SOD rates were not measured or calculated, they were assumed to be lower than the mainstem SOD rates. In the absence of specific measured data, the tributary SOD rates were assumed to be approximately 50% less than the values used for the mainstem of the Harpeth River. A value of 0.086 g-O_2/m^2/day (0.008 g-O_2/ft^2/day) was selected for the SOD rate for all of the tributary reaches.

Table 30. SOD rates used in the QUAL2E model

Reach number	Reach name	SOD (g-O_2/ft^2/day)
1	HR123.1-115.6	0.03
2	Cheatham Br	0.008
3	HR115.6-111.1	0.03
4	HR111.1-103.6	0.019
5	Arrington Cr	0.008
6	HR103.6-102.6	0.018
7	Starnes Cr	0.008
8	HR102.6-97.6	0.017
9	HR97.6-91.6	0.017
10	Fivemile Cr 1	0.008
11	UT to Fivemile	0.008
12	Fivemile Cr 2	0.008
13	HR91.6-89.6	0.017
14	Watson Br	0.008
15	HR89.6-88.6	0.017

Reaeration

During the April 2001 study, reaeration rates were measured to range between 5.27 and 12.12 day^{-1} (base e at 20 degrees Centigrade). However, these rates were measured during significantly different environmental conditions than were observed during the August 2000 study. Empirical equations to determine reaeration were investigated including all of the methods available in QUAL2E (Brown and Barnwell, 1987). However these equations were either not applicable for the environmental conditions being simulated by the model, or the equations resulted in rates which were several orders of magnitude lower than the rates measured in April 2001. Therefore, it was decided to uniformly apply a rate of 2.5 day^{-1} to all 15 reaches. This rate is within the same order of magnitude as those rates measured in April 2001, and it results in predicted instream DO concentrations which are reasonably close to the observed DO concentrations (Figure 54).

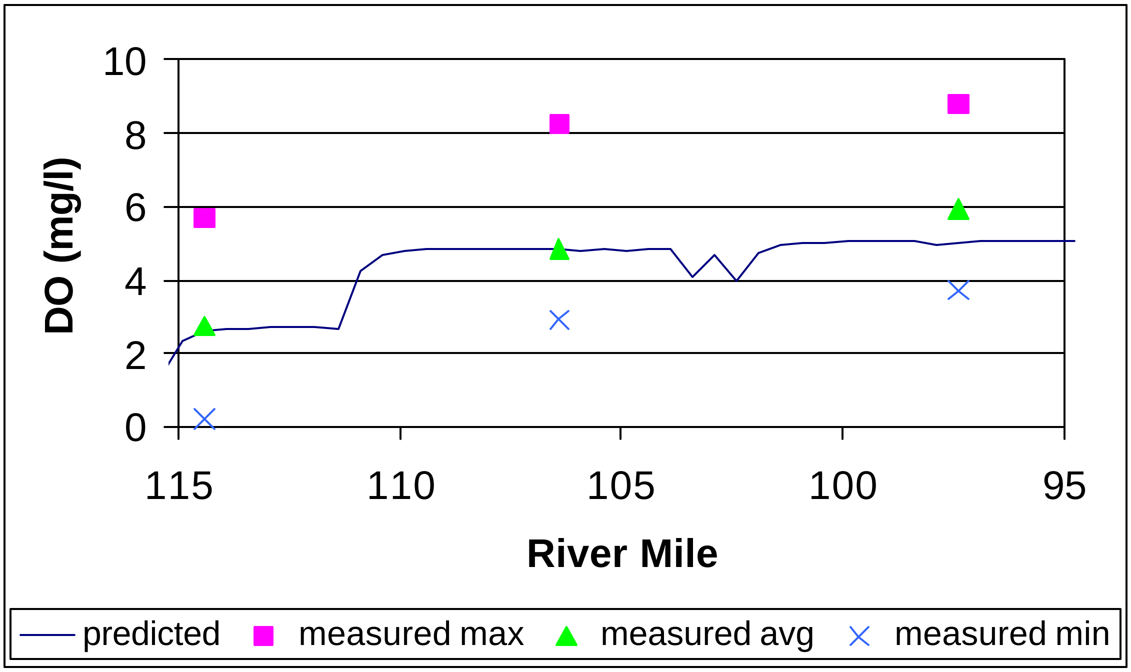


Figure 54. Comparison of predicted and measured DO concentrations

A copy of the QUAL2E model output file, which contains all of the model input information, is in Appendix A.

Using the Models to Develop TMDLs

This report is being made available to those stakeholders who have expressed interest in the TMDL process for the Harpeth River watershed. TDEC, with the cooperation of EPA, intends to use these models to propose TMDLs for the "organic enrichment/DO" impaired waters in the Harpeth River watershed by December 31, 2002 (i.e., 5 months from the date of this report). EPA and TDEC are encouraging input and welcome any comments concerning the modeling effort. Any information or comments provided to EPA or TDEC will be considered as part of the TMDL development process.

EPA requests that any comments on the modeling effort or any other aspects of this report should be submitted in writing by September 30, 2002 to Ms. Stephanie Fulton at the following address:

Stephanie Fulton
U.S. EPA Region 4
Water Management Division
Standards, Monitoring & TMDL Branch
West SMT Section
61 Forsyth Street, SW
Atlanta, Georgia 30303

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APPENDIX
QUAL2E Output

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                                                  * * * QUAL-2E  STREAM QUALITY ROUTING MODEL * * *
                                                Version 3.21  -  Feb. 1995

 $$$ (PROBLEM TITLES) $$$

CARD TYPE                              QUAL-2E PROGRAM TITLES
TITLE01             Harpeth River BOD calibration (tribs = 5.0)
TITLE02
TITLE03  NO         CONSERVATIVE MINERAL I
TITLE04  NO         CONSERVATIVE MINERAL II
TITLE05  NO         CONSERVATIVE MINERAL III
TITLE06  NO         TEMPERATURE
TITLE07  YES        BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES        ALGAE AS CHL-A IN UG/L
TITLE09  YES        PHOSPHORUS CYCLE AS P IN MG/L
TITLE10               (ORGANIC-P; DISSOLVED-P)
TITLE11  YES        NITROGEN CYCLE AS N IN MG/L
TITLE12               (ORGANIC-N; AMMONIA-N; NITRITE-N;' NITRATE-N)
TITLE13  YES        DISSOLVED OXYGEN IN MG/L
TITLE14  NO         FECAL COLIFORM IN NO./100 ML
TITLE15  NO         ARBITRARY NON-CONSERVATIVE
ENDTITLE

 $$$ DATA TYPE 1 (CONTROL DATA) $$$

CARD TYPE                                     CARD TYPE
LIST DATA INPUT            0.00000                                     0.00000
NO WRITE OPTIONAL SUMMARY  0.00000                                     0.00000
NO FLOW AUGMENTATION       0.00000                                     0.00000
STEADY STATE               0.00000                                     0.00000
NO TRAP CHANNELS           0.00000                                     0.00000
NO PRINT LCD/SOLAR DATA    0.00000                                     0.00000
NO PLOT DO AND BOD DATA    0.00000                                     0.00000
FIXED DNSTM CONC (YES=1)=  0.00000          5D-ULT BOD CONV K COEF  =  0.23000
INPUT METRIC           =   0.00000          OUTPUT METRIC           =  0.00000
NUMBER OF REACHES      =  15.00000          NUMBER OF JUNCTIONS     =  6.00000
NUM OF HEADWATERS      =   7.00000          NUMBER OF POINT LOADS   =  8.00000
TIME STEP (HOURS)      =   1.00000          LNTH. COMP. ELEMENT (DX)=  0.50000
MAXIMUM ROUTE TIME (HRS)= 30.00000          TIME INC. FOR RPT2 (HRS)=  1.00000
LATITUDE OF BASIN (DEG) = 36.00000          LONGITUDE OF BASIN (DEG)= 86.00000
STANDARD MARIDIAN (DEG) = 75.00000          DAY OF YEAR START TIME  = 235.00000
EVAP. COEF.,(AE)       =   0.00103          EVAP. COEF.,(BE)        =  0.00016
ELEV. OF BASIN (ELEV)   = 650.00000         DUST ATTENUATION COEF.  =  0.06000
ENDATA1                    0.00000                                     0.00000

 $$$ DATA TYPE 1A (ALGAE PRODUCTION AND NITROGEN OXIDATION CONSTANTS) $$$

CARD TYPE                                          CARD TYPE
O UPTAKE BY NH3 OXID(MG O/MG N)=    3.4300         O UPTAKE BY NO2 OXID(MG O/MG N)=    1.1400
O PROD  BY ALGAE (MG O/MG A)   =    1.6000         O UPTAKE BY ALGAE (MG O/MG A)  =    2.0000
N CONTENT OF ALGAE (MG N/MG A) =    0.0850         P CONTENT OF ALGAE (MG O/MG A) =    0.0140
ALG MAX SPEC GROWTH RATE(1/DAY)=    2.5000         ALGAE RESPIRATION RATE (1/DAY) =    0.0500
N HALF SATURATION CONST (MG/L) =    0.2000         P HALF SATURATION CONST (MG/L) =    0.0400
LIN ALG SHADE CO (1/FT-UGCHA/L=)    0.0008         NLIN SHADE(1/FT-(UGCHA/L)**2/3)=    0.0000
LIGHT FUNCTION OPTION (LFNOPT) =    1.0000         LIGHT SAT'N COEF (BTU/FT2-MIN) =    0.1100
DAILY AVERAGING OPTION (LAVOPT)=    2.0000         LIGHT AVERAGING FACTOR (AFACT) =    0.9200
NUMBER OF DAYLIGHT HOURS (DLH) =   13.0000         TOTAL DAILY SOLR RAD (BTU/FT-2)=  424.0000
ALGY GROWTH CALC OPTION(LGROPT)=    2.0000         ALGAL PREF FOR NH3-N (PREFN)   =    0.9000
ALG/TEMP SOLR RAD FACTOR(TFACT)=    0.4400         NITRIFICATION INHIBITION COEF  =   10.0000
ENDATA1A                            0.0000                                             0.0000

 $$$ DATA TYPE 1B (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$

CARD TYPE     RATE CODE     THETA VALUE

THETA( 1)      BOD DECA        1.047     USER
THETA( 2)      BOD SETT        1.024     USER
THETA( 3)      OXY TRAN        1.024     USER
THETA( 4)      SOD RATE        1.060     USER
THETA( 5)      ORGN DEC        1.047     USER
THETA( 6)      ORGN SET        1.024     USER
THETA( 7)      NH3 DECA        1.083     USER
THETA( 8)      NH3 SRCE        1.074     USER
THETA( 9)      NO2 DECA        1.047     USER
THETA(10)      PORG DEC        1.047     USER
THETA(11)      PORG SET        1.024     USER
THETA(12)      DISP SRC        1.074     USER
THETA(13)      ALG GROW        1.047     USER
THETA(14)      ALG RESP        1.047     USER
THETA(15)      ALG SETT        1.024     USER
THETA(16)      COLI DEC        1.047     DFLT
THETA(17)      ANC DECA        1.000     DFLT
THETA(18)      ANC SETT        1.024     DFLT
THETA(19)      ANC SRCE        1.000     DFLT
ENDATA1B

 $$$ DATA TYPE 2 (REACH IDENTIFICATION) $$$

CARD TYPE           REACH ORDER AND IDENT               R. MI/KM            R. MI/KM
STREAM REACH     1.0  RCH=   HR123.1-115.6   FROM        123.1     TO         115.6
STREAM REACH     2.0  RCH=     Cheatham Br   FROM          2.5     TO           0.0
STREAM REACH     3.0  RCH=   HR115.6-111.1   FROM        115.6     TO         111.1
STREAM REACH     4.0  RCH=   HR111.1-103.6   FROM        111.1     TO         103.6
STREAM REACH     5.0  RCH=    Arrington Cr   FROM          8.5     TO           0.0
STREAM REACH     6.0  RCH=   HR103.6-102.6   FROM        103.6     TO         102.6
```

STREAM REACH	7.0	RCH=	Starnes Cr	FROM	5.5	TO	0.0
STREAM REACH	8.0	RCH=	HR102.6-97.6	FROM	102.6	TO	97.6
STREAM REACH	9.0	RCH=	HR97.6-91.6	FROM	97.6	TO	91.6
STREAM REACH	10.0	RCH=	Fivemile Cr 1	FROM	5.0	TO	1.0
STREAM REACH	11.0	RCH=	UT to Fivemile	FROM	1.5	TO	0.0
STREAM REACH	12.0	RCH=	Fivemile Cr 2	FROM	1.0	TO	0.0
STREAM REACH	13.0	RCH=	HR91.6-89.6	FROM	91.6	TO	89.6
STREAM REACH	14.0	RCH=	Watson Br	FROM	5.0	TO	0.0
STREAM REACH	15.0	RCH=	HR89.6-88.6	FROM	89.6	TO	88.6
ENDATA2	0.0				0.0		0.0

$$$ DATA TYPE 3 (TARGET LEVEL DO AND FLOW AUGMENTATION SOURCES) $$$

CARD TYPE	REACH	AVAIL HDWS	TARGET	ORDER OF AVAIL SOURCES					
ENDATA3	0.	0.	0.0	0.	0.	0.	0.	0.	0.

$$$ DATA TYPE 4 (COMPUTATIONAL REACH FLAG FIELD) $$$

CARD TYPE	REACH	ELEMENTS/REACH	COMPUTATIONAL FLAGS
FLAG FIELD	1.	15.	1.2.2.2.2.2.2.2.2.2.2.2.2.2.3.0.0.0.0.0.
FLAG FIELD	2.	5.	1.6.2.2.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	3.	9.	4.2.2.2.2.2.2.2.6.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	4.	15.	2.2.2.2.2.2.2.2.2.2.6.2.6.2.3.0.0.0.0.0.
FLAG FIELD	5.	17.	1.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.0.0.0.
FLAG FIELD	6.	2.	4.3.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	7.	11.	1.2.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.
FLAG FIELD	8.	10.	4.6.2.2.2.2.2.2.2.6.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	9.	12.	2.2.2.2.2.2.2.2.2.2.2.3.0.0.0.0.0.0.0.0.
FLAG FIELD	10.	8.	1.2.2.2.2.6.2.3.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	11.	3.	1.6.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	12.	2.	4.2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	13.	4.	4.2.2.3.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	14.	10.	1.2.2.2.2.2.2.2.2.2.0.0.0.0.0.0.0.0.0.0.
FLAG FIELD	15.	2.	4.5.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.
ENDATA4	0.	0.	0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.

$$$ DATA TYPE 5 (HYDRAULIC DATA FOR DETERMINING VELOCITY AND DEPTH) $$$

CARD TYPE	REACH	COEF-DSPN	COEFQV	EXPOQV	COEFQH	EXPOQH	CMANN
HYDRAULICS	1.	60.00	0.030	0.000	0.080	0.000	0.020
HYDRAULICS	2.	60.00	0.010	0.000	0.050	0.000	0.020
HYDRAULICS	3.	60.00	0.034	0.000	0.100	0.000	0.020
HYDRAULICS	4.	60.00	0.034	0.000	0.100	0.000	0.020
HYDRAULICS	5.	60.00	0.010	0.000	0.050	0.000	0.020
HYDRAULICS	6.	60.00	0.033	0.000	0.100	0.000	0.020
HYDRAULICS	7.	60.00	0.010	0.000	0.030	0.000	0.020
HYDRAULICS	8.	60.00	0.032	0.000	0.100	0.000	0.020
HYDRAULICS	9.	60.00	0.031	0.000	0.100	0.000	0.020
HYDRAULICS	10.	60.00	0.010	0.000	0.080	0.000	0.020
HYDRAULICS	11.	60.00	0.020	0.000	0.040	0.000	0.020
HYDRAULICS	12.	60.00	0.020	0.000	0.100	0.000	0.020
HYDRAULICS	13.	60.00	0.025	0.000	0.200	0.000	0.020
HYDRAULICS	14.	60.00	0.010	0.000	0.030	0.000	0.020
HYDRAULICS	15.	60.00	0.020	0.000	0.200	0.000	0.020
ENDATA5	0.	0.00	0.000	0.000	0.000	0.000	0.000

$$$ DATA TYPE 5A (STEADY STATE TEMPERATURE AND CLIMATOLOGY DATA) $$$

CARD TYPE	REACH	ELEVATION	DUST COEF	CLOUD COVER	DRY BULB TEMP	WET BULB TEMP	ATM PRESSURE	WIND	SOLAR RAD ATTENUATION
TEMP/LCD	1.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	2.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	3.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	4.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	5.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	6.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	7.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	8.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	9.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	10.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	11.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	12.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	13.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	14.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
TEMP/LCD	15.	650.00	0.06	0.13	89.10	72.90	29.41	10.13	1.00
ENDATA5A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6 (REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION) $$$

CARD TYPE	REACH	K1	K3	SOD RATE	K2OPT	K2	COEQK2 TSIV COEF FOR OPT 8	OR OR	EXPQK2 SLOPE FOR OPT 8
REACT COEF	1.	0.02	0.00	0.030	1.	2.50	0.000		0.00700
REACT COEF	2.	0.02	0.00	0.010	1.	2.50	0.000		0.00700
REACT COEF	3.	0.02	0.00	0.030	1.	2.50	0.000		0.00700
REACT COEF	4.	0.02	0.00	0.019	1.	2.50	0.000		0.00400
REACT COEF	5.	0.02	0.00	0.010	1.	2.50	0.000		0.00300
REACT COEF	6.	0.02	0.00	0.018	1.	2.50	0.000		0.00400
REACT COEF	7.	0.02	0.00	0.010	1.	2.50	0.000		0.00300
REACT COEF	8.	0.02	0.00	0.017	1.	2.50	0.000		0.00400
REACT COEF	9.	0.02	0.00	0.017	1.	2.50	0.000		0.00500
REACT COEF	10.	0.02	0.00	0.010	1.	2.50	0.000		0.00300
REACT COEF	11.	0.02	0.00	0.010	1.	2.50	0.000		0.00300
REACT COEF	12.	0.02	0.00	0.010	1.	2.50	0.000		0.00300
REACT COEF	13.	0.02	0.00	0.017	1.	2.50	0.000		0.00500

REACT COEF	14.	0.02	0.00	0.010	1.	2.50	0.000	0.00300
REACT COEF	15.	0.02	0.00	0.017	1.	2.50	0.000	0.00500
ENDATA6	0.	0.00	0.00	0.000	0.	0.00	0.000	0.00000

$$$ DATA TYPE 6A (NITROGEN AND PHOSPHORUS CONSTANTS) $$$

CARD TYPE	REACH	CKNH2	SETNH2	CKNH3	SNH3	CKNO2	CKPORG	SETPORG	SPO4
N AND P COEF	1.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	2.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	3.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	4.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	5.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	6.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	7.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	8.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	9.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	10.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	11.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	12.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	13.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	14.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
N AND P COEF	15.	0.02	0.00	0.20	0.00	2.00	0.50	0.00	0.00
ENDATA6A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 6B (ALGAE/OTHER COEFFICIENTS) $$$

CARD TYPE	REACH	ALPHAO	ALGSET	EXCOEF	CK5 CKCOLI	CKANC	SETANC	SRCANC
ALG/OTHER COEF	1.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	2.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	3.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	4.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	5.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	6.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	7.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	8.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	9.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	10.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	11.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	12.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	13.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	14.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ALG/OTHER COEF	15.	10.00	1.00	0.01	0.00	0.00	0.00	0.00
ENDATA6B	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7 (INITIAL CONDITIONS) $$$

CARD TYPE	REACH	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INITIAL COND-1	1.	77.60	6.80	20.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	2.	77.60	5.70	10.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	3.	77.60	5.70	7.13	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	4.	76.30	7.80	5.61	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	5.	77.60	7.80	5.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	6.	77.60	7.80	4.50	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	7.	77.70	7.80	5.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	8.	77.70	7.80	4.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	9.	77.70	7.90	3.56	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	10.	77.70	7.90	5.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	11.	77.70	7.90	5.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	12.	77.70	7.90	5.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	13.	77.70	7.90	3.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	14.	77.70	7.90	3.00	0.00	0.00	0.00	0.00	0.00
INITIAL COND-1	15.	77.70	7.90	3.00	0.00	0.00	0.00	0.00	0.00
ENDATA7	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 7A (INITIAL CONDITIONS FOR CHOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INITIAL COND-2	1.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	2.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	3.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	4.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	5.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	6.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	7.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	8.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	9.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	10.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	11.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	12.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	13.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	14.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
INITIAL COND-2	15.	5.00	1.00	1.00	1.00	1.00	1.00	1.00
ENDATA7A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8 (INCREMENTAL INFLOW CONDITIONS) $$$

CARD TYPE	REACH	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INCR INFLOW-1	1.	0.018	70.00	5.00	10.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	2.	0.001	70.00	5.00	5.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	3.	0.000	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	4.	0.000	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	5.	0.002	70.00	5.00	5.50	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	6.	0.000	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	7.	0.001	70.00	5.00	9.50	0.00	0.00	0.00	0.00	0.00

INCR INFLOW-1	8.	0.000	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	9.	0.000	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	10.	0.001	70.00	5.00	2.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	11.	0.000	70.00	5.00	2.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	12.	0.000	70.00	5.00	2.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	13.	0.000	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	14.	0.001	70.00	5.00	8.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	15.	0.000	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA8	0.	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 8A (INCREMENTAL INFLOW CONDITIONS FOR CHLOROPHYLL A, NITROGEN, AND PHOSPHORUS) $$$

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INCR INFLOW-2	1.	5.00	0.90	0.10	0.01	0.09	0.15	0.15
INCR INFLOW-2	2.	5.00	0.90	0.10	0.01	0.09	0.15	0.15
INCR INFLOW-2	3.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-2	4.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-2	5.	5.00	0.20	0.10	0.01	0.09	0.15	0.15
INCR INFLOW-2	6.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-2	7.	5.00	0.20	0.10	0.01	0.09	0.15	0.15
INCR INFLOW-2	8.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-2	9.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-2	10.	5.00	0.20	0.10	0.01	0.09	0.15	0.15
INCR INFLOW-2	11.	5.00	0.20	0.10	0.01	0.09	0.15	0.15
INCR INFLOW-2	12.	5.00	0.20	0.10	0.01	0.09	0.15	0.15
INCR INFLOW-2	13.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-2	14.	5.00	0.20	0.10	0.01	0.09	0.15	0.15
INCR INFLOW-2	15.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENDATA8A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 9 (STREAM JUNCTIONS) $$$

CARD TYPE	JUNCTION ORDER AND IDENT			UPSTRM	JUNCTION	TRIB
STREAM JUNCTION	1.	JNC=	1	15.	21.	20.
STREAM JUNCTION	2.	JNC=	2	44.	62.	61.
STREAM JUNCTION	3.	JNC=	3	63.	75.	74.
STREAM JUNCTION	4.	JNC=	4	104.	108.	107.
STREAM JUNCTION	5.	JNC=	5	96.	110.	109.
STREAM JUNCTION	6.	JNC=	6	113.	124.	123.
ENDATA9	0.			0.	0.	0.

$$$ DATA TYPE 10 (HEADWATER SOURCES) $$$

CARD TYPE	HDWTR ORDER	NAME	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
HEADWTR-1	1.	HR123.1-115.6	0.00	77.60	5.00	10.00	0.00	0.00	0.00
HEADWTR-1	2.	Cheatham Br	0.00	77.60	5.00	5.00	0.00	0.00	0.00
HEADWTR-1	3.	Arrington Cr	0.00	77.70	5.00	5.50	0.00	0.00	0.00
HEADWTR-1	4.	Starnes Cr	0.00	77.70	5.00	9.50	0.00	0.00	0.00
HEADWTR-1	5.	Fivemile Cr 1	0.00	77.70	5.00	2.00	0.00	0.00	0.00
HEADWTR-1	6.	UT to Fivemile	0.00	77.70	5.00	2.00	0.00	0.00	0.00
HEADWTR-1	7.	Watson Br	0.00	77.70	5.00	8.00	0.00	0.00	0.00
ENDATA10	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 10A (HEADWATER CONDITIONS FOR CHLOROPHYLL, NITROGEN, PHOSPHORUS,
COLIFORM AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	HDWTR ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
HEADWTR-2	1.	0.00	0.00	5.00	1.00	0.10	0.00	0.10	0.15	0.15
HEADWTR-2	2.	0.00	0.00	5.00	1.00	0.10	0.00	0.10	0.15	0.15
HEADWTR-2	3.	0.00	0.00	5.00	1.00	0.10	0.00	0.10	0.15	0.15
HEADWTR-2	4.	0.00	0.00	5.00	1.00	0.10	0.00	0.10	0.15	0.15
HEADWTR-2	5.	0.00	0.00	5.00	1.00	0.10	0.00	0.10	0.15	0.15
HEADWTR-2	6.	0.00	0.00	5.00	1.00	0.10	0.00	0.10	0.15	0.15
HEADWTR-2	7.	0.00	0.00	5.00	1.00	0.10	0.00	0.10	0.15	0.15
ENDATA10A	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11 (POINT SOURCE / POINT SOURCE CHARACTERISTICS) $$$

CARD TYPE	POINT LOAD ORDER	NAME	EFF	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
POINTLD-1	1.	Eagleville S	0.00	0.00	77.60	6.70	6.14	0.00	0.00	0.00
POINTLD-1	2.	Overall Cr	0.00	0.00	77.60	5.00	5.00	0.00	0.00	0.00
POINTLD-1	3.	Nelson Cr	0.00	0.00	77.70	5.00	5.10	0.00	0.00	0.00
POINTLD-1	4.	McCrory Cr	0.00	0.00	77.70	5.00	4.20	0.00	0.00	0.00
POINTLD-1	5.	Page Middle	0.00	0.00	77.70	4.40	19.38	0.00	0.00	0.00
POINTLD-1	6.	Mayes Cr	0.00	0.00	77.70	5.00	4.00	0.00	0.00	0.00
POINTLD-1	7.	Goosecreek I	0.00	0.01	77.70	8.00	9.69	0.00	0.00	0.00
POINTLD-1	8.	Oakview Elem	0.00	0.00	77.70	6.80	9.69	0.00	0.00	0.00
ENDATA11	0.		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$$$ DATA TYPE 11A (POINT SOURCE CHARACTERISTICS - CHLOROPHYLL A, NITROGEN, PHOSPHORUS,
COLIFORMS AND SELECTED NON-CONSERVATIVE CONSTITUENT) $$$

CARD TYPE	POINT LOAD ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	N03-N	ORG-P	DIS-P
POINTLD-2	1.	0.00	0.00	5.00	5.00	0.95	0.50	4.50	4.00	4.00
POINTLD-2	2.	0.00	0.00	5.00	0.20	0.10	0.01	0.10	0.15	0.15
POINTLD-2	3.	0.00	0.00	5.00	0.20	0.10	0.01	0.10	0.15	0.15
POINTLD-2	4.	0.00	0.00	5.00	0.20	0.10	0.01	0.10	0.15	0.15
POINTLD-2	5.	0.00	0.00	5.00	10.00	5.00	1.00	9.00	4.00	4.00
POINTLD-2	6.	0.00	0.00	5.00	0.10	0.10	0.01	0.10	0.15	0.15

```
POINTLD-2       7.     0.00     0.00     5.00     5.00     0.37     0.50     4.50     4.00     4.00
POINTLD-2       8.     0.00     0.00     5.00     5.00     0.12     0.50     4.50     4.00     4.00
ENDATA11A       0.     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00

 $$$ DATA TYPE 12 (DAM CHARACTERISTICS) $$$

                      DAM   RCH   ELE    ADAM    BDAM    FDAM    HDAM

ENDATA12                 0.    0.    0.    0.00    0.00    0.00    0.00

 $$$ DATA TYPE 13 (DOWNSTREAM BOUNDARY CONDITIONS-1) $$$

     CARD TYPE               TEMP       D.O.      BOD       CM-1      CM-2      CM-3       ANC      COLI

ENDATA13                     DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED

 $$$ DATA TYPE 13A (DOWNSTREAM BOUNDARY CONDITIONS-2) $$$

     CARD TYPE               CHL-A     ORG-N     NH3-N     NO2-N     NH3-N     ORG-P     DIS-P

ENDATA13A                    DOWNSTREAM BOUNDARY CONCENTRATIONS ARE UNCONSTRAINED
```

STEADY STATE ALGAE/NUTRIENT/DISSOLVED OXYGEN SIMULATION; CONVERGENCE SUMMARY:

VARIABLE	ITERATION	NUMBER OF NONCONVERGENT ELEMENTS
ALGAE GROWTH RATE	1	125
ALGAE GROWTH RATE	2	125
ALGAE GROWTH RATE	3	119
ALGAE GROWTH RATE	4	116
ALGAE GROWTH RATE	5	85
ALGAE GROWTH RATE	6	60
ALGAE GROWTH RATE	7	0
ALGAE GROWTH RATE	8	0

SUMMARY OF CONDITIONS FOR ALGAL GROWTH RATE SIMULATION:

1. LIGHT AVERAGING OPTION.   LAVOPT= 2

   METHOD: MEAN SOLAR RADIATION DURING DAYLIGHT HOURS

   SOURCE OF SOLAR VALUES: DATA TYPE 1A
   DAILY NET SOLAR RADIATION: 424.000 BTU/FT-2 (115.061 LANGLEYS)
   NUMBER OF DAYLIGHT HOURS: 0.0
   PHOTOSYNTHETIC ACTIVE FRACTION OF SOLAR RADIATION (TFACT): N/A
   MEAN SOLAR RADIATION ADJUSTMENT FACTOR (AFACT): 0.920

2. LIGHT FUNCTION OPTION: LFNOPT= 1

   HALF SATURATION METHOD, WITH HALF SATURATION COEF = 0.030 LANGLEYS/MIN

3. GROWTH ATTENUATION OPTION FOR NUTRIENTS.   LGROPT= 2

   MINIMUM OF NITROGEN, PHOSPHORUS: FL*MIN(FN,FP)

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
1	1	1	123.10	122.60	0.00	0.00	0.00	0.030	1.019	0.080	0.499	0.11	1.74	0.04	0.02
2	1	2	122.60	122.10	0.00	0.00	0.00	0.030	1.019	0.080	0.998	0.21	3.06	0.08	0.02
3	1	3	122.10	121.60	0.00	0.00	0.00	0.030	1.019	0.080	1.497	0.32	4.38	0.12	0.02
4	1	4	121.60	121.10	0.00	0.00	0.00	0.030	1.019	0.080	1.996	0.42	5.69	0.16	0.02
5	1	5	121.10	120.60	0.01	0.00	0.00	0.030	1.019	0.080	2.495	0.53	7.01	0.20	0.02
6	1	6	120.60	120.10	0.01	0.00	0.00	0.030	1.019	0.080	2.994	0.63	8.33	0.24	0.02
7	1	7	120.10	119.60	0.01	0.00	0.00	0.030	1.019	0.080	3.493	0.74	9.64	0.28	0.02
8	1	8	119.60	119.10	0.01	0.00	0.00	0.030	1.019	0.080	3.992	0.84	10.96	0.32	0.02
9	1	9	119.10	118.60	0.01	0.00	0.00	0.030	1.019	0.080	4.491	0.95	12.28	0.36	0.02
10	1	10	118.60	118.10	0.01	0.00	0.00	0.030	1.019	0.080	4.990	1.05	13.60	0.40	0.02
11	1	11	118.10	117.60	0.01	0.00	0.00	0.030	1.019	0.080	5.489	1.16	14.91	0.44	0.02
12	1	12	117.60	117.10	0.01	0.00	0.00	0.030	1.019	0.080	5.988	1.26	16.23	0.48	0.02
13	1	13	117.10	116.60	0.02	0.00	0.00	0.030	1.019	0.080	6.487	1.37	17.55	0.52	0.02
14	1	14	116.60	116.10	0.02	0.00	0.00	0.030	1.019	0.080	6.986	1.48	18.87	0.56	0.02
15	1	15	116.10	115.60	0.02	0.00	0.00	0.030	1.019	0.080	7.485	1.58	20.18	0.60	0.02
16	2	1	2.50	2.00	0.00	0.00	0.00	0.010	3.056	0.050	0.518	0.07	1.63	0.03	0.00
17	2	2	2.00	1.50	0.00	0.00	0.00	0.010	3.056	0.050	2.529	0.33	6.94	0.13	0.00
18	2	3	1.50	1.00	0.00	0.00	0.00	0.010	3.056	0.050	3.045	0.40	8.30	0.15	0.00
19	2	4	1.00	0.50	0.00	0.00	0.00	0.010	3.056	0.050	3.560	0.47	9.66	0.18	0.00
20	2	5	0.50	0.00	0.00	0.00	0.00	0.010	3.056	0.050	4.076	0.54	11.02	0.20	0.00
21	3	1	115.60	115.10	0.02	0.00	0.00	0.034	0.899	0.100	5.883	1.55	16.06	0.59	0.02
22	3	2	115.10	114.60	0.02	0.00	0.00	0.034	0.899	0.100	5.883	1.55	16.06	0.59	0.02
23	3	3	114.60	114.10	0.02	0.00	0.00	0.034	0.899	0.100	5.883	1.55	16.06	0.59	0.02
24	3	4	114.10	113.60	0.02	0.00	0.00	0.034	0.899	0.100	5.883	1.55	16.06	0.59	0.02
25	3	5	113.60	113.10	0.02	0.00	0.00	0.034	0.899	0.100	5.883	1.55	16.06	0.59	0.02
26	3	6	113.10	112.60	0.02	0.00	0.00	0.034	0.899	0.100	5.883	1.55	16.06	0.59	0.02
27	3	7	112.60	112.10	0.02	0.00	0.00	0.034	0.899	0.100	5.883	1.55	16.06	0.59	0.02
28	3	8	112.10	111.60	0.02	0.00	0.00	0.034	0.899	0.100	5.883	1.55	16.06	0.59	0.02
29	3	9	111.60	111.10	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
30	4	1	111.10	110.60	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
31	4	2	110.60	110.10	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
32	4	3	110.10	109.60	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
33	4	4	109.60	109.10	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
34	4	5	109.10	108.60	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
35	4	6	108.60	108.10	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
36	4	7	108.10	107.60	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
37	4	8	107.60	107.10	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
38	4	9	107.10	106.60	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
39	4	10	106.60	106.10	0.02	0.00	0.00	0.034	0.899	0.100	6.229	1.64	16.97	0.62	0.02
40	4	11	106.10	105.60	0.02	0.00	0.00	0.034	0.899	0.100	6.655	1.76	18.10	0.67	0.02

STREAM QUALITY SIMULATION OUTPUT PAGE NUMBER 2
QUAL-2E STREAM QUALITY ROUTING MODEL Version 3.21 - Feb. 1995

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
41	4	12	105.60	105.10	0.02	0.00	0.00	0.034	0.899	0.100	6.655	1.76	18.10	0.67	0.02
42	4	13	105.10	104.60	0.02	0.00	0.00	0.034	0.899	0.100	7.052	1.86	19.15	0.71	0.02
43	4	14	104.60	104.10	0.02	0.00	0.00	0.034	0.899	0.100	7.052	1.86	19.15	0.71	0.02
44	4	15	104.10	103.60	0.02	0.00	0.00	0.034	0.899	0.100	7.052	1.86	19.15	0.71	0.02
45	5	1	8.50	8.00	0.00	0.00	0.00	0.010	3.056	0.050	0.255	0.03	0.94	0.01	0.00
46	5	2	8.00	7.50	0.00	0.00	0.00	0.010	3.056	0.050	0.507	0.07	1.60	0.03	0.00
47	5	3	7.50	7.00	0.00	0.00	0.00	0.010	3.056	0.050	0.760	0.10	2.27	0.04	0.00
48	5	4	7.00	6.50	0.00	0.00	0.00	0.010	3.056	0.050	1.012	0.13	2.94	0.05	0.00
49	5	5	6.50	6.00	0.00	0.00	0.00	0.010	3.056	0.050	1.265	0.17	3.60	0.06	0.00
50	5	6	6.00	5.50	0.00	0.00	0.00	0.010	3.056	0.050	1.518	0.20	4.27	0.08	0.00
51	5	7	5.50	5.00	0.00	0.00	0.00	0.010	3.056	0.050	1.770	0.23	4.94	0.09	0.00
52	5	8	5.00	4.50	0.00	0.00	0.00	0.010	3.056	0.050	2.023	0.27	5.60	0.10	0.00
53	5	9	4.50	4.00	0.00	0.00	0.00	0.010	3.056	0.050	2.275	0.30	6.27	0.11	0.00
54	5	10	4.00	3.50	0.00	0.00	0.00	0.010	3.056	0.050	2.528	0.33	6.94	0.13	0.00
55	5	11	3.50	3.00	0.00	0.00	0.00	0.010	3.056	0.050	2.780	0.37	7.60	0.14	0.00
56	5	12	3.00	2.50	0.00	0.00	0.00	0.010	3.056	0.050	3.033	0.40	8.27	0.15	0.00
57	5	13	2.50	2.00	0.00	0.00	0.00	0.010	3.056	0.050	3.286	0.43	8.94	0.16	0.00
58	5	14	2.00	1.50	0.00	0.00	0.00	0.010	3.056	0.050	3.538	0.47	9.60	0.18	0.00
59	5	15	1.50	1.00	0.00	0.00	0.00	0.010	3.056	0.050	3.791	0.50	10.27	0.19	0.00
60	5	16	1.00	0.50	0.00	0.00	0.00	0.010	3.056	0.050	4.043	0.53	10.94	0.20	0.00
61	5	17	0.50	0.00	0.00	0.00	0.00	0.010	3.056	0.050	4.296	0.57	11.61	0.21	0.00
62	6	1	103.60	103.10	0.03	0.00	0.00	0.033	0.926	0.100	7.917	2.09	21.43	0.79	0.02
63	6	2	103.10	102.60	0.03	0.00	0.00	0.033	0.926	0.100	7.917	2.09	21.43	0.79	0.02
64	7	1	5.50	5.00	0.00	0.00	0.00	0.010	3.056	0.030	0.215	0.02	0.73	0.01	0.00
65	7	2	5.00	4.50	0.00	0.00	0.00	0.010	3.056	0.030	0.427	0.03	1.29	0.01	0.00
66	7	3	4.50	4.00	0.00	0.00	0.00	0.010	3.056	0.030	0.639	0.05	1.84	0.02	0.00
67	7	4	4.00	3.50	0.00	0.00	0.00	0.010	3.056	0.030	0.851	0.07	2.40	0.03	0.00
68	7	5	3.50	3.00	0.00	0.00	0.00	0.010	3.056	0.030	1.062	0.08	2.96	0.03	0.00
69	7	6	3.00	2.50	0.00	0.00	0.00	0.010	3.056	0.030	1.274	0.10	3.52	0.04	0.00
70	7	7	2.50	2.00	0.00	0.00	0.00	0.010	3.056	0.030	1.486	0.12	4.08	0.04	0.00
71	7	8	2.00	1.50	0.00	0.00	0.00	0.010	3.056	0.030	1.698	0.13	4.64	0.05	0.00
72	7	9	1.50	1.00	0.00	0.00	0.00	0.010	3.056	0.030	1.910	0.15	5.20	0.06	0.00
73	7	10	1.00	0.50	0.00	0.00	0.00	0.010	3.056	0.030	2.122	0.17	5.76	0.06	0.00
74	7	11	0.50	0.00	0.00	0.00	0.00	0.010	3.056	0.030	2.333	0.18	6.32	0.07	0.00
75	8	1	102.60	102.10	0.03	0.00	0.00	0.032	0.955	0.100	8.383	2.21	22.66	0.84	0.02
76	8	2	102.10	101.60	0.03	0.00	0.00	0.032	0.955	0.100	8.475	2.24	22.90	0.85	0.02
77	8	3	101.60	101.10	0.03	0.00	0.00	0.032	0.955	0.100	8.475	2.24	22.90	0.85	0.02
78	8	4	101.10	100.60	0.03	0.00	0.00	0.032	0.955	0.100	8.475	2.24	22.90	0.85	0.02

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
79	8	5	100.60	100.10	0.03	0.00	0.00	0.032	0.955	0.100	8.475	2.24	22.90	0.85	0.02
80	8	6	100.10	99.60	0.03	0.00	0.00	0.032	0.955	0.100	8.475	2.24	22.90	0.85	0.02
81	8	7	99.60	99.10	0.03	0.00	0.00	0.032	0.955	0.100	8.475	2.24	22.90	0.85	0.02
82	8	8	99.10	98.60	0.03	0.00	0.00	0.032	0.955	0.100	8.475	2.24	22.90	0.85	0.02
83	8	9	98.60	98.10	0.03	0.00	0.00	0.032	0.955	0.100	8.475	2.24	22.90	0.85	0.02
84	8	10	98.10	97.60	0.03	0.00	0.00	0.032	0.955	0.100	9.468	2.50	25.52	0.95	0.02
85	9	1	97.60	97.10	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
86	9	2	97.10	96.60	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
87	9	3	96.60	96.10	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
88	9	4	96.10	95.60	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
89	9	5	95.60	95.10	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
90	9	6	95.10	94.60	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
91	9	7	94.60	94.10	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
92	9	8	94.10	93.60	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
93	9	9	93.60	93.10	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
94	9	10	93.10	92.60	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
95	9	11	92.60	92.10	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
96	9	12	92.10	91.60	0.03	0.00	0.00	0.031	0.986	0.100	9.774	2.58	26.33	0.98	0.02
97	10	1	5.00	4.50	0.00	0.00	0.00	0.010	3.056	0.080	0.171	0.04	0.87	0.01	0.01
98	10	2	4.50	4.00	0.00	0.00	0.00	0.010	3.056	0.080	0.340	0.07	1.32	0.03	0.01
99	10	3	4.00	3.50	0.00	0.00	0.00	0.010	3.056	0.080	0.510	0.11	1.77	0.04	0.01
100	10	4	3.50	3.00	0.00	0.00	0.00	0.010	3.056	0.080	0.679	0.14	2.22	0.05	0.01
101	10	5	3.00	2.50	0.00	0.00	0.00	0.010	3.056	0.080	0.849	0.18	2.66	0.07	0.01
102	10	6	2.50	2.00	0.01	0.01	0.00	0.010	3.056	0.080	7.620	1.61	20.54	0.61	0.01
103	10	7	2.00	1.50	0.01	0.00	0.00	0.010	3.056	0.080	7.789	1.65	20.99	0.62	0.01
104	10	8	1.50	1.00	0.01	0.00	0.00	0.010	3.056	0.080	7.959	1.68	21.43	0.64	0.01
105	11	1	1.50	1.00	0.00	0.00	0.00	0.020	1.528	0.040	0.055	0.01	0.36	0.00	0.01
106	11	2	1.00	0.50	0.00	0.00	0.00	0.020	1.528	0.040	3.309	0.35	8.95	0.13	0.01
107	11	3	0.50	0.00	0.00	0.00	0.00	0.020	1.528	0.040	3.363	0.36	9.09	0.13	0.01
108	12	1	1.00	0.50	0.01	0.00	0.00	0.020	1.528	0.100	4.544	1.20	12.53	0.45	0.01
109	12	2	0.50	0.00	0.01	0.00	0.00	0.020	1.528	0.100	4.561	1.20	12.57	0.46	0.01
110	13	1	91.60	91.10	0.04	0.00	0.00	0.025	1.222	0.200	7.884	4.16	21.87	1.58	0.03
111	13	2	91.10	90.60	0.04	0.00	0.00	0.025	1.222	0.200	7.884	4.16	21.87	1.58	0.03
112	13	3	90.60	90.10	0.04	0.00	0.00	0.025	1.222	0.200	7.884	4.16	21.87	1.58	0.03
113	13	4	90.10	89.60	0.04	0.00	0.00	0.025	1.222	0.200	7.884	4.16	21.87	1.58	0.03

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME K-FT-3	BOTTOM AREA K-FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
114	14	1	5.00	4.50	0.00	0.00	0.00	0.010	3.056	0.030	0.204	0.02	0.70	0.01	0.00
115	14	2	4.50	4.00	0.00	0.00	0.00	0.010	3.056	0.030	0.404	0.03	1.22	0.01	0.00
116	14	3	4.00	3.50	0.00	0.00	0.00	0.010	3.056	0.030	0.604	0.05	1.75	0.02	0.00
117	14	4	3.50	3.00	0.00	0.00	0.00	0.010	3.056	0.030	0.805	0.06	2.28	0.02	0.00
118	14	5	3.00	2.50	0.00	0.00	0.00	0.010	3.056	0.030	1.005	0.08	2.81	0.03	0.00
119	14	6	2.50	2.00	0.00	0.00	0.00	0.010	3.056	0.030	1.205	0.10	3.34	0.04	0.00
120	14	7	2.00	1.50	0.00	0.00	0.00	0.010	3.056	0.030	1.406	0.11	3.87	0.04	0.00
121	14	8	1.50	1.00	0.00	0.00	0.00	0.010	3.056	0.030	1.606	0.13	4.40	0.05	0.00
122	14	9	1.00	0.50	0.00	0.00	0.00	0.010	3.056	0.030	1.806	0.14	4.93	0.05	0.00
123	14	10	0.50	0.00	0.00	0.00	0.00	0.010	3.056	0.030	2.007	0.16	5.46	0.06	0.00
124	15	1	89.60	89.10	0.04	0.00	0.00	0.020	1.528	0.200	10.005	5.28	27.47	2.00	0.02
125	15	2	89.10	88.60	0.04	0.00	0.00	0.020	1.528	0.200	10.005	5.28	27.47	2.00	0.02

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
1	1	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	2	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	3	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	4	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	5	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	6	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	7	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	8	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	9	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	10	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	11	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	12	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	13	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	14	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
1	15	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
2	1	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
2	2	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
2	3	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
2	4	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
2	5	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
3	1	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
3	2	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
3	3	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
3	4	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
3	5	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
3	6	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
3	7	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
3	8	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
3	9	8.07	1	2.84	0.03	0.00	0.04	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
4	1	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	2	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	3	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	4	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	5	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	6	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	7	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	8	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	9	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	10	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	11	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
4	12	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	13	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	14	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
4	15	8.18	1	2.79	0.02	0.00	0.02	0.02	0.00	0.29	0.00	2.47	0.62	0.00	0.00	0.00	0.00	0.00	0.00
5	1	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	2	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	3	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	4	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	5	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	6	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	7	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	8	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	9	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	10	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	11	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	12	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	13	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	14	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	15	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	16	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
5	17	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
6	1	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
6	2	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	1	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	2	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	3	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	4	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	5	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	6	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	7	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	8	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	9	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	10	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
7	11	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
8	1	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
8	2	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
8	3	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
8	4	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
8	5	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
8	6	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
8	7	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
8	8	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
8	9	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
8	10	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	1	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	2	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	3	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	4	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	5	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	6	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	7	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	8	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	9	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	10	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	11	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
9	12	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
10	1	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
10	2	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
10	3	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
10	4	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
10	5	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
10	6	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
10	7	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
10	8	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
11	1	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
11	2	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
11	3	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
12	1	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
12	2	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
13	1	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
13	2	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
13	3	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
13	4	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
14	1	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
14	2	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
14	3	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
14	4	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
14	5	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
14	6	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
14	7	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
14	8	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
14	9	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
14	10	8.07	1	2.84	0.03	0.00	0.01	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
15	1	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00
15	2	8.07	1	2.84	0.03	0.00	0.02	0.03	0.00	0.31	0.00	2.56	0.64	0.00	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
1	1	77.60	0.00	0.00	0.00	0.00	9.87	0.89	0.10	0.01	0.10	1.10	0.11	0.19	0.30	0.00	0.00	0.63
1	2	77.60	0.00	0.00	0.00	0.00	9.75	0.88	0.09	0.01	0.12	1.10	0.09	0.21	0.30	0.00	0.00	0.25
1	3	77.60	0.00	0.00	0.00	0.00	9.62	0.87	0.09	0.01	0.13	1.10	0.07	0.23	0.30	0.00	0.00	0.15
1	4	77.60	0.00	0.00	0.00	0.40	9.50	0.86	0.09	0.01	0.15	1.10	0.06	0.24	0.30	0.00	0.00	0.10
1	5	77.60	0.00	0.00	0.00	0.66	9.38	0.84	0.09	0.01	0.16	1.10	0.05	0.25	0.30	0.00	0.00	0.08
1	6	77.60	0.00	0.00	0.00	0.84	9.26	0.83	0.08	0.01	0.17	1.10	0.04	0.26	0.30	0.00	0.00	0.07
1	7	77.60	0.00	0.00	0.00	0.95	9.15	0.82	0.08	0.01	0.18	1.10	0.04	0.26	0.30	0.00	0.00	0.06
1	8	77.60	0.00	0.00	0.00	1.04	9.03	0.81	0.08	0.01	0.19	1.10	0.03	0.27	0.30	0.00	0.00	0.05
1	9	77.60	0.00	0.00	0.00	1.10	8.92	0.80	0.08	0.01	0.21	1.10	0.03	0.27	0.30	0.00	0.00	0.04
1	10	77.60	0.00	0.00	0.00	1.16	8.81	0.79	0.08	0.01	0.22	1.10	0.02	0.28	0.30	0.00	0.00	0.04
1	11	77.60	0.00	0.00	0.00	1.20	8.70	0.78	0.08	0.01	0.23	1.10	0.02	0.28	0.30	0.00	0.00	0.03
1	12	77.60	0.00	0.00	0.00	1.23	8.60	0.77	0.07	0.01	0.24	1.10	0.02	0.28	0.30	0.00	0.00	0.03
1	13	77.60	0.00	0.00	0.00	1.26	8.49	0.76	0.07	0.01	0.25	1.10	0.02	0.28	0.30	0.00	0.00	0.03
1	14	77.60	0.00	0.00	0.00	1.29	8.39	0.76	0.07	0.01	0.26	1.10	0.02	0.28	0.30	0.00	0.00	0.03
1	15	77.60	0.00	0.00	0.00	1.31	8.29	0.75	0.07	0.01	0.27	1.10	0.02	0.28	0.30	0.00	0.00	0.03
2	1	77.60	0.00	0.00	0.00	0.86	4.81	0.87	0.09	0.01	0.13	1.10	0.08	0.22	0.30	0.00	0.00	0.14
2	2	77.60	0.00	0.00	0.00	2.41	5.38	3.17	0.48	0.10	3.18	6.92	1.11	3.75	4.85	0.00	0.00	0.10
2	3	77.60	0.00	0.00	0.00	3.90	4.96	2.60	0.32	0.04	2.97	5.94	0.34	3.74	4.08	0.00	0.00	0.02
2	4	77.60	0.00	0.00	0.00	4.14	4.63	2.19	0.24	0.03	2.77	5.24	0.11	3.42	3.53	0.00	0.00	0.01
2	5	77.60	0.00	0.00	0.00	4.22	4.36	1.89	0.19	0.02	2.60	4.71	0.04	3.08	3.13	0.00	0.00	0.01
3	1	77.60	0.00	0.00	0.00	1.38	7.75	0.85	0.08	0.01	0.53	1.47	0.01	0.57	0.59	0.00	0.00	0.00
3	2	77.60	0.00	0.00	0.00	2.33	7.57	0.83	0.08	0.01	0.55	1.47	0.01	0.58	0.59	0.00	0.00	0.00
3	3	77.60	0.00	0.00	0.00	2.59	7.40	0.81	0.08	0.01	0.57	1.47	0.01	0.58	0.59	0.00	0.00	0.00
3	4	77.60	0.00	0.00	0.00	2.67	7.24	0.79	0.07	0.01	0.59	1.47	0.00	0.58	0.59	0.00	0.00	0.00
3	5	77.60	0.00	0.00	0.00	2.69	7.07	0.77	0.07	0.01	0.61	1.47	0.00	0.59	0.59	0.00	0.00	0.00
3	6	77.60	0.00	0.00	0.00	2.70	6.92	0.76	0.07	0.01	0.63	1.47	0.00	0.59	0.59	0.00	0.00	0.00
3	7	77.60	0.00	0.00	0.00	2.70	6.76	0.74	0.07	0.01	0.65	1.47	0.00	0.59	0.59	0.00	0.00	0.00
3	8	77.60	0.00	0.00	0.00	2.71	6.61	0.72	0.07	0.01	0.67	1.47	0.00	0.59	0.59	0.00	0.00	0.00
3	9	77.60	0.00	0.00	0.00	2.65	6.38	0.68	0.07	0.01	0.65	1.41	0.01	0.57	0.57	0.00	0.00	0.03
4	1	76.30	0.00	0.00	0.00	4.22	6.24	0.66	0.06	0.01	0.67	1.41	0.00	0.57	0.57	0.00	0.00	0.00
4	2	76.30	0.00	0.00	0.00	4.67	6.10	0.65	0.06	0.01	0.69	1.41	0.00	0.57	0.57	0.00	0.00	0.00
4	3	76.30	0.00	0.00	0.00	4.80	5.97	0.64	0.06	0.01	0.70	1.41	0.00	0.57	0.57	0.00	0.00	0.00
4	4	76.30	0.00	0.00	0.00	4.84	5.84	0.62	0.06	0.01	0.72	1.41	0.00	0.57	0.57	0.00	0.00	0.00
4	5	76.30	0.00	0.00	0.00	4.85	5.71	0.61	0.06	0.01	0.73	1.41	0.00	0.57	0.57	0.00	0.00	0.00
4	6	76.30	0.00	0.00	0.00	4.85	5.59	0.59	0.06	0.01	0.75	1.41	0.00	0.57	0.57	0.00	0.00	0.00
4	7	76.30	0.00	0.00	0.00	4.86	5.47	0.58	0.05	0.01	0.76	1.41	0.00	0.57	0.57	0.00	0.00	0.00
4	8	76.30	0.00	0.00	0.00	4.86	5.35	0.57	0.05	0.01	0.78	1.41	0.00	0.57	0.57	0.00	0.00	0.00
4	9	76.30	0.00	0.00	0.00	4.86	5.23	0.56	0.05	0.01	0.79	1.41	0.00	0.57	0.57	0.00	0.00	0.00
4	10	76.30	0.00	0.00	0.00	4.86	5.12	0.54	0.05	0.01	0.81	1.41	0.00	0.57	0.57	0.00	0.00	0.00
4	11	76.30	0.00	0.00	0.00	4.79	5.01	0.51	0.05	0.01	0.77	1.34	0.01	0.55	0.55	0.00	0.00	0.03

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
4	12	76.30	0.00	0.00	0.00	4.85	4.90	0.50	0.05	0.01	0.79	1.34	0.00	0.55	0.55	0.00	0.00	0.00
4	13	76.30	0.00	0.00	0.00	4.81	4.76	0.47	0.05	0.01	0.76	1.29	0.01	0.53	0.54	0.00	0.00	0.03
4	14	76.30	0.00	0.00	0.00	4.86	4.66	0.46	0.05	0.01	0.77	1.29	0.01	0.53	0.54	0.00	0.00	0.00
4	15	76.30	0.00	0.00	0.00	4.87	4.55	0.45	0.05	0.01	0.79	1.29	0.00	0.54	0.54	0.00	0.00	0.00
5	1	77.60	0.00	0.00	0.00	0.00	5.29	0.20	0.07	0.01	0.13	0.41	0.08	0.22	0.30	0.00	0.00	0.14
5	2	77.60	0.00	0.00	0.00	2.56	5.10	0.19	0.06	0.01	0.15	0.40	0.05	0.25	0.30	0.00	0.00	0.05
5	3	77.60	0.00	0.00	0.00	3.39	4.91	0.18	0.05	0.01	0.17	0.40	0.03	0.27	0.30	0.00	0.00	0.03
5	4	77.60	0.00	0.00	0.00	3.75	4.73	0.17	0.04	0.00	0.18	0.40	0.02	0.28	0.30	0.00	0.00	0.02
5	5	77.60	0.00	0.00	0.00	3.95	4.57	0.17	0.03	0.00	0.19	0.40	0.02	0.28	0.30	0.00	0.00	0.02
5	6	77.60	0.00	0.00	0.00	4.07	4.41	0.16	0.03	0.00	0.20	0.40	0.01	0.29	0.30	0.00	0.00	0.01
5	7	77.60	0.00	0.00	0.00	4.16	4.25	0.16	0.03	0.00	0.21	0.40	0.01	0.29	0.30	0.00	0.00	0.01
5	8	77.60	0.00	0.00	0.00	4.22	4.11	0.15	0.03	0.00	0.22	0.40	0.01	0.29	0.30	0.00	0.00	0.01
5	9	77.60	0.00	0.00	0.00	4.27	3.97	0.14	0.02	0.00	0.23	0.40	0.01	0.29	0.30	0.00	0.00	0.01
5	10	77.60	0.00	0.00	0.00	4.31	3.84	0.14	0.02	0.00	0.23	0.40	0.01	0.29	0.30	0.00	0.00	0.01
5	11	77.60	0.00	0.00	0.00	4.34	3.71	0.14	0.02	0.00	0.24	0.40	0.01	0.29	0.30	0.00	0.00	0.01
5	12	77.60	0.00	0.00	0.00	4.37	3.59	0.13	0.02	0.00	0.25	0.40	0.01	0.29	0.30	0.00	0.00	0.01
5	13	77.60	0.00	0.00	0.00	4.39	3.48	0.13	0.02	0.00	0.25	0.40	0.01	0.29	0.30	0.00	0.00	0.01
5	14	77.60	0.00	0.00	0.00	4.41	3.37	0.12	0.02	0.00	0.26	0.40	0.01	0.29	0.30	0.00	0.00	0.01
5	15	77.60	0.00	0.00	0.00	4.43	3.26	0.12	0.02	0.00	0.26	0.40	0.01	0.29	0.30	0.00	0.00	0.01
5	16	77.60	0.00	0.00	0.00	4.44	3.16	0.12	0.02	0.00	0.27	0.40	0.00	0.29	0.30	0.00	0.00	0.00
5	17	77.60	0.00	0.00	0.00	4.46	3.07	0.11	0.02	0.00	0.27	0.40	0.00	0.30	0.30	0.00	0.00	0.00
6	1	77.60	0.00	0.00	0.00	4.07	4.36	0.42	0.04	0.01	0.75	1.22	0.00	0.52	0.52	0.00	0.00	0.00
6	2	77.60	0.00	0.00	0.00	4.66	4.26	0.41	0.04	0.00	0.76	1.22	0.00	0.52	0.52	0.00	0.00	0.00
7	1	77.70	0.00	0.00	0.00	0.00	9.14	0.20	0.07	0.01	0.13	0.41	0.08	0.22	0.30	0.00	0.00	0.08
7	2	77.70	0.00	0.00	0.00	0.00	8.80	0.19	0.06	0.01	0.15	0.41	0.05	0.25	0.30	0.00	0.00	0.03
7	3	77.70	0.00	0.00	0.00	0.62	8.48	0.18	0.05	0.01	0.17	0.40	0.03	0.27	0.30	0.00	0.00	0.02
7	4	77.70	0.00	0.00	0.00	1.11	8.17	0.17	0.04	0.01	0.18	0.40	0.02	0.28	0.30	0.00	0.00	0.01
7	5	77.70	0.00	0.00	0.00	1.38	7.88	0.17	0.03	0.00	0.20	0.40	0.02	0.28	0.30	0.00	0.00	0.01
7	6	77.70	0.00	0.00	0.00	1.55	7.60	0.16	0.03	0.00	0.21	0.40	0.01	0.29	0.30	0.00	0.00	0.01
7	7	77.70	0.00	0.00	0.00	1.67	7.34	0.16	0.03	0.00	0.21	0.40	0.01	0.29	0.30	0.00	0.00	0.01
7	8	77.70	0.00	0.00	0.00	1.76	7.09	0.15	0.03	0.00	0.22	0.40	0.01	0.29	0.30	0.00	0.00	0.01
7	9	77.70	0.00	0.00	0.00	1.83	6.85	0.15	0.02	0.00	0.23	0.40	0.01	0.29	0.30	0.00	0.00	0.01
7	10	77.70	0.00	0.00	0.00	1.88	6.62	0.14	0.02	0.00	0.24	0.40	0.01	0.29	0.30	0.00	0.00	0.00
7	11	77.70	0.00	0.00	0.00	1.93	6.40	0.14	0.02	0.00	0.24	0.40	0.01	0.29	0.30	0.00	0.00	0.00
8	1	77.70	0.00	0.00	0.00	3.96	4.24	0.39	0.04	0.00	0.76	1.20	0.00	0.51	0.51	0.00	0.00	0.00
8	2	77.70	0.00	0.00	0.00	4.73	4.30	0.49	0.08	0.01	0.87	1.45	0.03	0.57	0.60	0.00	0.00	0.01
8	3	77.70	0.00	0.00	0.00	4.95	4.20	0.48	0.07	0.01	0.90	1.45	0.02	0.58	0.60	0.00	0.00	0.00
8	4	77.70	0.00	0.00	0.00	5.01	4.10	0.46	0.06	0.01	0.92	1.45	0.01	0.58	0.60	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
8	5	77.70	0.00	0.00	0.00	5.03	4.00	0.45	0.06	0.01	0.94	1.45	0.01	0.59	0.60	0.00	0.00	0.00
8	6	77.70	0.00	0.00	0.00	5.04	3.91	0.44	0.05	0.01	0.95	1.45	0.00	0.59	0.60	0.00	0.00	0.00
8	7	77.70	0.00	0.00	0.00	5.04	3.81	0.43	0.05	0.01	0.97	1.45	0.00	0.59	0.60	0.00	0.00	0.00
8	8	77.70	0.00	0.00	0.00	5.04	3.72	0.42	0.05	0.01	0.98	1.45	0.00	0.59	0.60	0.00	0.00	0.00
8	9	77.70	0.00	0.00	0.00	5.05	3.63	0.41	0.04	0.01	0.99	1.45	0.00	0.59	0.60	0.00	0.00	0.00
8	10	77.70	0.00	0.00	0.00	4.94	3.59	0.37	0.05	0.01	0.91	1.33	0.01	0.55	0.56	0.00	0.00	0.05
9	1	77.70	0.00	0.00	0.00	4.99	3.50	0.36	0.04	0.01	0.93	1.33	0.01	0.56	0.56	0.00	0.00	0.00
9	2	77.70	0.00	0.00	0.00	5.04	3.41	0.35	0.04	0.00	0.94	1.33	0.00	0.56	0.56	0.00	0.00	0.00
9	3	77.70	0.00	0.00	0.00	5.06	3.33	0.34	0.04	0.00	0.95	1.33	0.00	0.56	0.56	0.00	0.00	0.00
9	4	77.70	0.00	0.00	0.00	5.06	3.25	0.33	0.03	0.00	0.96	1.33	0.00	0.56	0.56	0.00	0.00	0.00
9	5	77.70	0.00	0.00	0.00	5.07	3.17	0.33	0.03	0.00	0.97	1.33	0.00	0.56	0.56	0.00	0.00	0.00
9	6	77.70	0.00	0.00	0.00	5.07	3.09	0.32	0.03	0.00	0.98	1.33	0.00	0.56	0.56	0.00	0.00	0.00
9	7	77.70	0.00	0.00	0.00	5.07	3.01	0.31	0.03	0.00	0.99	1.33	0.00	0.56	0.56	0.00	0.00	0.00
9	8	77.70	0.00	0.00	0.00	5.07	2.94	0.30	0.03	0.00	1.00	1.33	0.00	0.56	0.56	0.00	0.00	0.00
9	9	77.70	0.00	0.00	0.00	5.07	2.87	0.30	0.03	0.00	1.01	1.33	0.00	0.56	0.56	0.00	0.00	0.00
9	10	77.70	0.00	0.00	0.00	5.07	2.80	0.29	0.03	0.00	1.01	1.33	0.00	0.56	0.56	0.00	0.00	0.00
9	11	77.70	0.00	0.00	0.00	5.07	2.73	0.28	0.03	0.00	1.02	1.33	0.00	0.56	0.56	0.00	0.00	0.00
9	12	77.70	0.00	0.00	0.00	5.07	2.66	0.27	0.03	0.00	1.03	1.33	0.00	0.56	0.56	0.00	0.00	0.00
10	1	77.70	0.00	0.00	0.00	0.80	1.92	0.20	0.07	0.01	0.12	0.40	0.08	0.22	0.30	0.00	0.00	0.23
10	2	77.70	0.00	0.00	0.00	3.73	1.85	0.19	0.06	0.01	0.15	0.40	0.05	0.25	0.30	0.00	0.00	0.08
10	3	77.70	0.00	0.00	0.00	4.61	1.79	0.18	0.05	0.01	0.17	0.40	0.03	0.27	0.30	0.00	0.00	0.05
10	4	77.70	0.00	0.00	0.00	4.99	1.72	0.17	0.04	0.00	0.18	0.40	0.02	0.28	0.30	0.00	0.00	0.03
10	5	77.70	0.00	0.00	0.00	5.20	1.66	0.17	0.03	0.00	0.19	0.40	0.02	0.28	0.30	0.00	0.00	0.03
10	6	77.70	0.00	0.00	0.00	4.50	8.26	4.17	0.33	0.11	4.41	9.03	1.66	5.31	6.97	0.00	0.00	0.19
10	7	77.70	0.00	0.00	0.00	5.52	7.54	3.79	0.32	0.05	4.68	8.84	0.56	6.27	6.82	0.00	0.00	0.01
10	8	77.70	0.00	0.00	0.00	5.64	6.89	3.45	0.30	0.04	4.88	8.67	0.19	6.50	6.69	0.00	0.00	0.00
11	1	77.70	0.00	0.00	0.00	0.00	1.96	0.21	0.08	0.01	0.11	0.42	0.10	0.20	0.30	0.00	0.00	0.22
11	2	77.70	0.00	0.00	0.00	1.47	9.25	4.75	0.17	0.18	4.70	9.80	2.59	5.16	7.75	0.00	0.00	0.22
11	3	77.70	0.00	0.00	0.00	3.08	8.80	4.50	0.24	0.06	4.86	9.65	1.29	6.34	7.63	0.00	0.00	0.01
12	1	77.70	0.00	0.00	0.00	5.68	7.19	3.62	0.29	0.04	4.98	8.93	0.27	6.67	6.94	0.00	0.00	0.00
12	2	77.70	0.00	0.00	0.00	6.00	6.90	3.47	0.29	0.03	5.10	8.90	0.14	6.78	6.92	0.00	0.00	0.00
13	1	77.70	0.00	0.00	0.00	5.50	3.57	1.00	0.09	0.01	1.99	3.08	0.02	2.01	2.04	0.00	0.00	0.00
13	2	77.70	0.00	0.00	0.00	6.26	3.46	0.96	0.08	0.01	2.02	3.08	0.01	2.02	2.04	0.00	0.00	0.00
13	3	77.70	0.00	0.00	0.00	6.42	3.36	0.94	0.08	0.01	2.06	3.08	0.01	2.03	2.04	0.00	0.00	0.00
13	4	77.70	0.00	0.00	0.00	6.46	3.26	0.91	0.08	0.01	2.09	3.08	0.00	2.03	2.04	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
14	1	77.70	0.00	0.00	0.00	0.00	7.69	0.21	0.07	0.01	0.13	0.41	0.08	0.22	0.30	0.00	0.00	0.08
14	2	77.70	0.00	0.00	0.00	0.00	7.41	0.19	0.06	0.01	0.15	0.41	0.05	0.25	0.30	0.00	0.00	0.03
14	3	77.70	0.00	0.00	0.00	0.59	7.14	0.18	0.05	0.01	0.17	0.40	0.03	0.27	0.30	0.00	0.00	0.02
14	4	77.70	0.00	0.00	0.00	1.10	6.88	0.17	0.04	0.01	0.18	0.40	0.02	0.28	0.30	0.00	0.00	0.01
14	5	77.70	0.00	0.00	0.00	1.37	6.64	0.17	0.03	0.00	0.20	0.40	0.02	0.28	0.30	0.00	0.00	0.01
14	6	77.70	0.00	0.00	0.00	1.55	6.40	0.16	0.03	0.00	0.21	0.40	0.01	0.29	0.30	0.00	0.00	0.01
14	7	77.70	0.00	0.00	0.00	1.67	6.18	0.16	0.03	0.00	0.21	0.40	0.01	0.29	0.30	0.00	0.00	0.01
14	8	77.70	0.00	0.00	0.00	1.76	5.97	0.15	0.03	0.00	0.22	0.40	0.01	0.29	0.30	0.00	0.00	0.01
14	9	77.70	0.00	0.00	0.00	1.83	5.77	0.15	0.02	0.00	0.23	0.40	0.01	0.29	0.30	0.00	0.00	0.01
14	10	77.70	0.00	0.00	0.00	1.88	5.58	0.14	0.02	0.00	0.24	0.40	0.01	0.29	0.30	0.00	0.00	0.00
15	1	77.70	0.00	0.00	0.00	5.76	3.21	0.87	0.08	0.01	2.08	3.04	0.00	2.01	2.01	0.00	0.00	0.00
15	2	77.70	0.00	0.00	0.00	6.36	3.09	0.84	0.08	0.01	2.12	3.04	0.00	2.01	2.01	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
1	1	1	0.63	0.66	0.06	1.13	8.27	0.06	0.90	0.89	0.01	0.41	0.50	0.82
2	1	2	0.25	0.68	0.06	1.13	8.49	0.02	0.90	0.88	0.01	0.41	0.51	0.84
3	1	3	0.15	0.70	0.06	1.13	8.71	0.01	0.90	0.86	0.01	0.41	0.53	0.85
4	1	4	0.10	0.71	0.06	1.13	8.91	0.01	0.90	0.84	0.01	0.41	0.54	0.86
5	1	5	0.08	0.73	0.06	1.13	9.10	0.01	0.90	0.83	0.01	0.41	0.55	0.86
6	1	6	0.07	0.74	0.06	1.13	9.28	0.01	0.90	0.81	0.01	0.41	0.56	0.87
7	1	7	0.06	0.75	0.06	1.13	9.44	0.01	0.90	0.80	0.01	0.41	0.57	0.87
8	1	8	0.05	0.77	0.06	1.13	9.60	0.01	0.90	0.79	0.01	0.41	0.58	0.87
9	1	9	0.04	0.78	0.06	1.13	9.75	0.00	0.90	0.77	0.01	0.41	0.59	0.87
10	1	10	0.04	0.79	0.06	1.13	9.88	0.00	0.90	0.76	0.01	0.41	0.60	0.87
11	1	11	0.03	0.80	0.06	1.13	10.02	0.00	0.90	0.75	0.01	0.41	0.60	0.87
12	1	12	0.03	0.81	0.06	1.13	10.14	0.00	0.90	0.74	0.01	0.41	0.61	0.87
13	1	13	0.03	0.82	0.06	1.13	10.26	0.00	0.90	0.73	0.01	0.41	0.62	0.88
14	1	14	0.03	0.83	0.06	1.13	10.37	0.00	0.90	0.71	0.01	0.41	0.63	0.88
15	1	15	0.03	0.84	0.06	1.13	10.47	0.00	0.90	0.70	0.01	0.41	0.63	0.88
16	2	1	0.14	0.70	0.06	1.13	8.73	0.01	0.90	0.86	0.01	0.41	0.53	0.85
17	2	2	0.10	1.26	0.06	1.13	15.72	0.02	0.90	0.58	0.01	0.41	0.95	0.99
18	2	3	0.02	1.25	0.06	1.13	15.63	0.00	0.90	0.49	0.01	0.41	0.94	0.99
19	2	4	0.01	1.24	0.06	1.13	15.55	0.00	0.90	0.44	0.01	0.41	0.94	0.99
20	2	5	0.01	1.24	0.06	1.13	15.47	0.00	0.90	0.40	0.01	0.41	0.93	0.99
21	3	1	0.00	1.00	0.06	1.13	12.48	0.00	0.90	0.58	0.01	0.41	0.75	0.93
22	3	2	0.00	1.00	0.06	1.13	12.57	0.00	0.90	0.56	0.01	0.41	0.76	0.94
23	3	3	0.00	1.01	0.06	1.13	12.66	0.00	0.90	0.55	0.01	0.41	0.76	0.94
24	3	4	0.00	1.02	0.06	1.13	12.75	0.00	0.90	0.53	0.01	0.41	0.77	0.94
25	3	5	0.00	1.02	0.06	1.13	12.82	0.00	0.90	0.51	0.01	0.41	0.77	0.94
26	3	6	0.00	1.03	0.06	1.13	12.90	0.00	0.90	0.50	0.01	0.41	0.78	0.94
27	3	7	0.00	1.04	0.06	1.13	12.97	0.00	0.90	0.49	0.01	0.41	0.78	0.94
28	3	8	0.00	1.04	0.06	1.13	13.03	0.00	0.90	0.47	0.01	0.41	0.79	0.94
29	3	9	0.03	1.04	0.06	1.13	12.98	0.00	0.90	0.48	0.01	0.41	0.78	0.93
30	4	1	0.00	1.01	0.06	1.12	13.03	0.00	0.90	0.46	0.01	0.41	0.79	0.93
31	4	2	0.00	1.01	0.06	1.12	13.09	0.00	0.90	0.45	0.01	0.41	0.79	0.93
32	4	3	0.00	1.02	0.06	1.12	13.14	0.00	0.90	0.44	0.01	0.41	0.79	0.93
33	4	4	0.00	1.02	0.06	1.12	13.19	0.00	0.90	0.43	0.01	0.41	0.80	0.93
34	4	5	0.00	1.02	0.06	1.12	13.24	0.00	0.90	0.41	0.01	0.41	0.80	0.93
35	4	6	0.00	1.03	0.06	1.12	13.28	0.00	0.90	0.40	0.01	0.41	0.80	0.93
36	4	7	0.00	1.03	0.06	1.12	13.32	0.00	0.90	0.39	0.01	0.41	0.80	0.93
37	4	8	0.00	1.03	0.06	1.12	13.36	0.00	0.90	0.38	0.01	0.41	0.81	0.93
38	4	9	0.00	1.04	0.06	1.12	13.40	0.00	0.90	0.37	0.01	0.41	0.81	0.93
39	4	10	0.00	1.04	0.06	1.12	13.44	0.00	0.90	0.36	0.01	0.41	0.81	0.93
40	4	11	0.03	1.03	0.06	1.12	13.34	0.00	0.90	0.38	0.01	0.41	0.80	0.93

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
41	4	12	0.00	1.03	0.06	1.12	13.38	0.00	0.90	0.36	0.01	0.41	0.81	0.93
42	4	13	0.03	1.03	0.06	1.12	13.30	0.00	0.90	0.37	0.01	0.41	0.80	0.93
43	4	14	0.00	1.03	0.06	1.12	13.33	0.00	0.90	0.36	0.01	0.41	0.80	0.93
44	4	15	0.00	1.03	0.06	1.12	13.36	0.00	0.90	0.35	0.01	0.41	0.81	0.93
45	5	1	0.14	0.66	0.06	1.13	8.24	0.01	0.90	0.84	0.01	0.41	0.50	0.85
46	5	2	0.05	0.67	0.06	1.13	8.42	0.00	0.90	0.77	0.01	0.41	0.51	0.86
47	5	3	0.03	0.69	0.06	1.13	8.58	0.00	0.90	0.71	0.01	0.41	0.52	0.87
48	5	4	0.02	0.70	0.06	1.13	8.72	0.00	0.90	0.66	0.01	0.41	0.53	0.87
49	5	5	0.02	0.71	0.06	1.13	8.84	0.00	0.90	0.61	0.01	0.41	0.53	0.88
50	5	6	0.01	0.72	0.06	1.13	8.96	0.00	0.90	0.57	0.01	0.41	0.54	0.88
51	5	7	0.01	0.72	0.06	1.13	9.06	0.00	0.90	0.54	0.01	0.41	0.55	0.88
52	5	8	0.01	0.73	0.06	1.13	9.15	0.00	0.90	0.51	0.01	0.41	0.55	0.88
53	5	9	0.01	0.74	0.06	1.13	9.24	0.00	0.90	0.48	0.01	0.41	0.56	0.88
54	5	10	0.01	0.74	0.06	1.13	9.32	0.00	0.90	0.46	0.01	0.41	0.56	0.88
55	5	11	0.01	0.75	0.06	1.13	9.39	0.00	0.90	0.44	0.01	0.41	0.57	0.88
56	5	12	0.01	0.76	0.06	1.13	9.46	0.00	0.90	0.42	0.01	0.41	0.57	0.88
57	5	13	0.01	0.76	0.06	1.13	9.53	0.00	0.90	0.40	0.01	0.41	0.57	0.88
58	5	14	0.01	0.77	0.06	1.13	9.59	0.00	0.90	0.38	0.01	0.41	0.58	0.88
59	5	15	0.01	0.77	0.06	1.13	9.64	0.00	0.90	0.37	0.01	0.41	0.58	0.88
60	5	16	0.00	0.77	0.06	1.13	9.70	0.00	0.90	0.35	0.01	0.41	0.58	0.88
61	5	17	0.00	0.78	0.06	1.13	9.75	0.00	0.90	0.34	0.01	0.41	0.59	0.88
62	6	1	0.00	1.06	0.06	1.13	13.24	0.00	0.90	0.34	0.01	0.41	0.80	0.93
63	6	2	0.00	1.06	0.06	1.13	13.27	0.00	0.90	0.32	0.01	0.41	0.80	0.93
64	7	1	0.08	0.66	0.06	1.14	8.26	0.01	0.90	0.84	0.01	0.41	0.50	0.85
65	7	2	0.03	0.68	0.06	1.14	8.44	0.00	0.90	0.77	0.01	0.41	0.51	0.86
66	7	3	0.02	0.69	0.06	1.14	8.60	0.00	0.90	0.71	0.01	0.41	0.52	0.87
67	7	4	0.01	0.70	0.06	1.14	8.74	0.00	0.90	0.66	0.01	0.41	0.53	0.87
68	7	5	0.01	0.71	0.06	1.14	8.86	0.00	0.90	0.61	0.01	0.41	0.53	0.88
69	7	6	0.01	0.72	0.06	1.14	8.97	0.00	0.90	0.57	0.01	0.41	0.54	0.88
70	7	7	0.01	0.73	0.06	1.14	9.07	0.00	0.90	0.54	0.01	0.41	0.55	0.88
71	7	8	0.01	0.73	0.06	1.14	9.17	0.00	0.90	0.51	0.01	0.41	0.55	0.88
72	7	9	0.01	0.74	0.06	1.14	9.25	0.00	0.90	0.48	0.01	0.41	0.56	0.88
73	7	10	0.00	0.75	0.06	1.14	9.33	0.00	0.90	0.46	0.01	0.41	0.56	0.88
74	7	11	0.00	0.75	0.06	1.14	9.41	0.00	0.90	0.43	0.01	0.41	0.57	0.88
75	8	1	0.00	1.06	0.06	1.14	13.25	0.00	0.90	0.32	0.01	0.41	0.80	0.93
76	8	2	0.01	1.10	0.06	1.14	13.71	0.00	0.90	0.45	0.01	0.41	0.83	0.93
77	8	3	0.00	1.10	0.06	1.14	13.74	0.00	0.90	0.42	0.01	0.41	0.83	0.94
78	8	4	0.00	1.10	0.06	1.14	13.77	0.00	0.90	0.39	0.01	0.41	0.83	0.94

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
79	8	5	0.00	1.10	0.06	1.14	13.80	0.00	0.90	0.36	0.01	0.41	0.83	0.94
80	8	6	0.00	1.11	0.06	1.14	13.83	0.00	0.90	0.33	0.01	0.41	0.83	0.94
81	8	7	0.00	1.11	0.06	1.14	13.85	0.00	0.90	0.31	0.01	0.41	0.84	0.94
82	8	8	0.00	1.11	0.06	1.14	13.87	0.00	0.90	0.30	0.01	0.41	0.84	0.94
83	8	9	0.00	1.11	0.06	1.14	13.90	0.00	0.90	0.28	0.01	0.41	0.84	0.94
84	8	10	0.05	1.10	0.06	1.14	13.71	0.01	0.90	0.31	0.01	0.41	0.83	0.93
85	9	1	0.00	1.10	0.06	1.14	13.74	0.00	0.90	0.29	0.01	0.41	0.83	0.93
86	9	2	0.00	1.10	0.06	1.14	13.76	0.00	0.90	0.27	0.01	0.41	0.83	0.93
87	9	3	0.00	1.10	0.06	1.14	13.78	0.00	0.90	0.26	0.01	0.41	0.83	0.93
88	9	4	0.00	1.10	0.06	1.14	13.80	0.00	0.90	0.24	0.01	0.41	0.83	0.93
89	9	5	0.00	1.11	0.06	1.14	13.82	0.00	0.90	0.23	0.01	0.41	0.83	0.93
90	9	6	0.00	1.11	0.06	1.14	13.84	0.00	0.90	0.22	0.01	0.41	0.83	0.93
91	9	7	0.00	1.11	0.06	1.14	13.86	0.00	0.90	0.21	0.01	0.41	0.84	0.93
92	9	8	0.00	1.11	0.06	1.14	13.87	0.00	0.90	0.21	0.01	0.41	0.84	0.93
93	9	9	0.00	1.11	0.06	1.14	13.89	0.00	0.90	0.20	0.01	0.41	0.84	0.93
94	9	10	0.00	1.11	0.06	1.14	13.91	0.00	0.90	0.19	0.01	0.41	0.84	0.93
95	9	11	0.00	1.11	0.06	1.14	13.92	0.00	0.90	0.19	0.01	0.41	0.84	0.93
96	9	12	0.00	1.12	0.06	1.14	13.94	0.00	0.90	0.18	0.01	0.41	0.84	0.93
97	10	1	0.23	0.66	0.06	1.14	8.23	0.02	0.90	0.84	0.01	0.41	0.50	0.85
98	10	2	0.08	0.67	0.06	1.14	8.41	0.01	0.90	0.77	0.01	0.41	0.51	0.86
99	10	3	0.05	0.69	0.06	1.14	8.57	0.00	0.90	0.71	0.01	0.41	0.52	0.87
100	10	4	0.03	0.70	0.06	1.14	8.71	0.00	0.90	0.66	0.01	0.41	0.53	0.87
101	10	5	0.03	0.71	0.06	1.14	8.85	0.00	0.90	0.61	0.01	0.41	0.53	0.88
102	10	6	0.19	1.27	0.06	1.14	15.91	0.04	0.90	0.40	0.01	0.41	0.96	0.99
103	10	7	0.01	1.28	0.06	1.14	15.94	0.00	0.90	0.38	0.01	0.41	0.96	0.99
104	10	8	0.00	1.28	0.06	1.14	15.96	0.00	0.90	0.36	0.01	0.41	0.96	0.99
105	11	1	0.22	0.65	0.06	1.14	8.16	0.02	0.90	0.87	0.01	0.41	0.49	0.83
106	11	2	0.22	1.27	0.06	1.14	15.92	0.04	0.90	0.25	0.01	0.41	0.96	0.99
107	11	3	0.01	1.28	0.06	1.14	15.95	0.00	0.90	0.30	0.01	0.41	0.96	0.99
108	12	1	0.00	1.28	0.06	1.14	15.97	0.00	0.90	0.34	0.01	0.41	0.96	0.99
109	12	2	0.00	1.28	0.06	1.14	15.98	0.00	0.90	0.34	0.01	0.41	0.96	0.99
110	13	1	0.00	1.21	0.06	1.14	15.12	0.00	0.90	0.28	0.01	0.41	0.91	0.98
111	13	2	0.00	1.21	0.06	1.14	15.14	0.00	0.90	0.27	0.01	0.41	0.91	0.98
112	13	3	0.00	1.21	0.06	1.14	15.16	0.00	0.90	0.27	0.01	0.41	0.91	0.98
113	13	4	0.00	1.22	0.06	1.14	15.17	0.00	0.90	0.26	0.01	0.41	0.92	0.98

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
114	14	1	0.08	0.66	0.06	1.14	8.26	0.01	0.90	0.84	0.01	0.41	0.50	0.85
115	14	2	0.03	0.68	0.06	1.14	8.44	0.00	0.90	0.77	0.01	0.41	0.51	0.86
116	14	3	0.02	0.69	0.06	1.14	8.60	0.00	0.90	0.71	0.01	0.41	0.52	0.87
117	14	4	0.01	0.70	0.06	1.14	8.74	0.00	0.90	0.66	0.01	0.41	0.53	0.87
118	14	5	0.01	0.71	0.06	1.14	8.86	0.00	0.90	0.61	0.01	0.41	0.53	0.88
119	14	6	0.01	0.72	0.06	1.14	8.97	0.00	0.90	0.57	0.01	0.41	0.54	0.88
120	14	7	0.01	0.73	0.06	1.14	9.07	0.00	0.90	0.54	0.01	0.41	0.55	0.88
121	14	8	0.01	0.73	0.06	1.14	9.17	0.00	0.90	0.51	0.01	0.41	0.55	0.88
122	14	9	0.01	0.74	0.06	1.14	9.25	0.00	0.90	0.48	0.01	0.41	0.56	0.88
123	14	10	0.00	0.75	0.06	1.14	9.34	0.00	0.90	0.46	0.01	0.41	0.56	0.88
124	15	1	0.00	1.21	0.06	1.14	15.17	0.00	0.90	0.25	0.01	0.41	0.92	0.98
125	15	2	0.00	1.22	0.06	1.14	15.19	0.00	0.90	0.24	0.01	0.41	0.92	0.98

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY) F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
1	1	1	77.60	8.07	0.00	8.07	0.00	1.00	4.91	22.91	-0.25	-18.07	0.06	-0.10	-0.03
2	1	2	77.60	8.07	0.00	8.07	0.00	1.00	2.45	22.91	-0.25	-18.07	0.02	-0.10	-0.03
3	1	3	77.60	8.07	0.00	8.07	0.00	1.00	1.64	22.91	-0.25	-18.07	0.01	-0.09	-0.03
4	1	4	77.60	8.07	0.40	7.68	0.00	1.00	1.23	21.79	-0.24	-18.07	0.01	-0.09	-0.03
5	1	5	77.60	8.07	0.66	7.41	0.00	1.00	0.98	21.02	-0.24	-18.07	0.01	-0.09	-0.03
6	1	6	77.60	8.07	0.84	7.24	0.00	1.00	0.82	20.54	-0.24	-18.07	0.01	-0.09	-0.03
7	1	7	77.60	8.07	0.95	7.12	0.00	1.00	0.70	20.21	-0.23	-18.07	0.01	-0.09	-0.03
8	1	8	77.60	8.07	1.04	7.04	0.00	1.00	0.61	19.96	-0.23	-18.07	0.01	-0.08	-0.03
9	1	9	77.60	8.07	1.10	6.97	0.00	1.00	0.55	19.78	-0.23	-18.07	0.00	-0.08	-0.03
10	1	10	77.60	8.07	1.16	6.92	0.00	1.00	0.49	19.63	-0.23	-18.07	0.00	-0.08	-0.03
11	1	11	77.60	8.07	1.20	6.88	0.00	1.00	0.45	19.51	-0.22	-18.07	0.00	-0.08	-0.03
12	1	12	77.60	8.07	1.23	6.84	0.00	1.00	0.41	19.41	-0.22	-18.07	0.00	-0.08	-0.03
13	1	13	77.60	8.07	1.26	6.81	0.00	1.00	0.38	19.32	-0.22	-18.07	0.00	-0.08	-0.03
14	1	14	77.60	8.07	1.29	6.78	0.00	1.00	0.35	19.25	-0.21	-18.07	0.00	-0.08	-0.03
15	1	15	77.60	8.07	1.31	6.76	0.00	1.00	0.33	19.19	-0.21	-18.07	0.00	-0.08	-0.03
16	2	1	77.60	8.07	0.86	7.21	0.00	1.00	1.64	20.46	-0.12	-9.64	0.01	-0.09	-0.03
17	2	2	77.60	8.07	2.41	5.66	0.00	1.00	1.63	16.07	-0.14	-9.64	0.02	-0.50	-0.29
18	2	3	77.60	8.07	3.90	4.18	0.00	1.00	0.28	11.85	-0.13	-9.64	0.00	-0.34	-0.13
19	2	4	77.60	8.07	4.14	3.94	0.00	1.00	0.24	11.17	-0.12	-9.64	0.00	-0.25	-0.09
20	2	5	77.60	8.07	4.22	3.85	0.00	1.00	0.21	10.92	-0.11	-9.64	0.00	-0.20	-0.07
21	3	1	77.60	8.07	1.38	6.69	0.00	1.00	0.00	18.98	-0.20	-14.46	0.00	-0.09	-0.03
22	3	2	77.60	8.07	2.33	5.75	0.00	1.00	0.00	16.31	-0.19	-14.46	0.00	-0.08	-0.03
23	3	3	77.60	8.07	2.59	5.48	0.00	1.00	0.00	15.55	-0.19	-14.46	0.00	-0.08	-0.03
24	3	4	77.60	8.07	2.67	5.40	0.00	1.00	0.00	15.33	-0.18	-14.46	0.00	-0.08	-0.03
25	3	5	77.60	8.07	2.69	5.38	0.00	1.00	0.00	15.27	-0.18	-14.46	0.00	-0.08	-0.03
26	3	6	77.60	8.07	2.70	5.37	0.00	1.00	0.00	15.24	-0.18	-14.46	0.00	-0.07	-0.02
27	3	7	77.60	8.07	2.70	5.37	0.00	1.00	0.00	15.23	-0.17	-14.46	0.00	-0.07	-0.02
28	3	8	77.60	8.07	2.71	5.37	0.00	1.00	0.00	15.23	-0.17	-14.46	0.00	-0.07	-0.02
29	3	9	77.60	8.07	2.65	5.43	0.00	1.00	0.31	15.40	-0.16	-14.46	0.00	-0.07	-0.02
30	4	1	76.30	8.18	4.22	3.96	0.00	1.00	0.00	11.05	-0.15	-8.78	0.00	-0.06	-0.02
31	4	2	76.30	8.18	4.67	3.51	0.00	1.00	0.00	9.80	-0.15	-8.78	0.00	-0.06	-0.02
32	4	3	76.30	8.18	4.80	3.38	0.00	1.00	0.00	9.44	-0.15	-8.78	0.00	-0.06	-0.02
33	4	4	76.30	8.18	4.84	3.35	0.00	1.00	0.00	9.33	-0.14	-8.78	0.00	-0.06	-0.02
34	4	5	76.30	8.18	4.85	3.33	0.00	1.00	0.00	9.30	-0.14	-8.78	0.00	-0.06	-0.02
35	4	6	76.30	8.18	4.85	3.33	0.00	1.00	0.00	9.29	-0.14	-8.78	0.00	-0.06	-0.02
36	4	7	76.30	8.18	4.86	3.33	0.00	1.00	0.00	9.28	-0.14	-8.78	0.00	-0.05	-0.02
37	4	8	76.30	8.18	4.86	3.32	0.00	1.00	0.00	9.27	-0.13	-8.78	0.00	-0.05	-0.02
38	4	9	76.30	8.18	4.86	3.32	0.00	1.00	0.00	9.27	-0.13	-8.78	0.00	-0.05	-0.02
39	4	10	76.30	8.18	4.86	3.32	0.00	1.00	0.00	9.26	-0.13	-8.78	0.00	-0.05	-0.02
40	4	11	76.30	8.18	4.79	3.39	0.00	1.00	0.36	9.45	-0.12	-8.78	0.00	-0.05	-0.02

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
									COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)						
41	4	12	76.30	8.18	4.85	3.33	0.00	1.00	0.00	9.30	-0.12	-8.78	0.00	-0.05	-0.02
42	4	13	76.30	8.18	4.81	3.38	0.00	1.00	0.31	9.42	-0.12	-8.78	0.00	-0.05	-0.02
43	4	14	76.30	8.18	4.86	3.32	0.00	1.00	0.00	9.27	-0.12	-8.78	0.00	-0.05	-0.02
44	4	15	76.30	8.18	4.87	3.31	0.00	1.00	0.00	9.23	-0.11	-8.78	0.00	-0.05	-0.02
45	5	1	77.60	8.07	0.00	8.07	0.00	1.00	1.64	22.91	-0.14	-9.64	0.01	-0.08	-0.03
46	5	2	77.60	8.07	2.56	5.52	0.00	1.00	0.81	15.66	-0.13	-9.64	0.00	-0.06	-0.02
47	5	3	77.60	8.07	3.39	4.68	0.00	1.00	0.54	13.29	-0.13	-9.64	0.00	-0.05	-0.02
48	5	4	77.60	8.07	3.75	4.32	0.00	1.00	0.41	12.27	-0.12	-9.64	0.00	-0.04	-0.01
49	5	5	77.60	8.07	3.95	4.13	0.00	1.00	0.33	11.71	-0.12	-9.64	0.00	-0.04	-0.01
50	5	6	77.60	8.07	4.07	4.00	0.00	1.00	0.27	11.35	-0.11	-9.64	0.00	-0.03	-0.01
51	5	7	77.60	8.07	4.16	3.91	0.00	1.00	0.23	11.10	-0.11	-9.64	0.00	-0.03	-0.01
52	5	8	77.60	8.07	4.22	3.85	0.00	1.00	0.20	10.92	-0.11	-9.64	0.00	-0.03	-0.01
53	5	9	77.60	8.07	4.27	3.80	0.00	1.00	0.18	10.78	-0.10	-9.64	0.00	-0.02	-0.01
54	5	10	77.60	8.07	4.31	3.76	0.00	1.00	0.16	10.67	-0.10	-9.64	0.00	-0.02	-0.01
55	5	11	77.60	8.07	4.34	3.73	0.00	1.00	0.15	10.58	-0.09	-9.64	0.00	-0.02	-0.01
56	5	12	77.60	8.07	4.37	3.70	0.00	1.00	0.14	10.51	-0.09	-9.64	0.00	-0.02	-0.01
57	5	13	77.60	8.07	4.39	3.68	0.00	1.00	0.13	10.44	-0.09	-9.64	0.00	-0.02	-0.01
58	5	14	77.60	8.07	4.41	3.66	0.00	1.00	0.12	10.39	-0.09	-9.64	0.00	-0.02	-0.01
59	5	15	77.60	8.07	4.43	3.64	0.00	1.00	0.11	10.34	-0.08	-9.64	0.00	-0.02	-0.01
60	5	16	77.60	8.07	4.44	3.63	0.00	1.00	0.10	10.30	-0.08	-9.64	0.00	-0.02	-0.01
61	5	17	77.60	8.07	4.46	3.62	0.00	1.00	0.10	10.26	-0.08	-9.64	0.00	-0.02	-0.01
62	6	1	77.60	8.07	4.07	4.00	0.00	1.00	0.00	11.36	-0.11	-8.68	0.00	-0.04	-0.01
63	6	2	77.60	8.07	4.66	3.42	0.00	1.00	0.00	9.70	-0.11	-8.68	0.00	-0.04	-0.01
64	7	1	77.70	8.07	0.00	8.07	0.00	1.00	1.64	22.92	-0.23	-16.12	0.01	-0.08	-0.03
65	7	2	77.70	8.07	0.00	8.07	0.00	1.00	0.81	22.92	-0.23	-16.12	0.00	-0.06	-0.02
66	7	3	77.70	8.07	0.62	7.45	0.00	1.00	0.54	21.16	-0.22	-16.12	0.00	-0.05	-0.02
67	7	4	77.70	8.07	1.11	6.96	0.00	1.00	0.41	19.76	-0.21	-16.12	0.00	-0.04	-0.01
68	7	5	77.70	8.07	1.38	6.68	0.00	1.00	0.33	18.99	-0.20	-16.12	0.00	-0.04	-0.01
69	7	6	77.70	8.07	1.55	6.51	0.00	1.00	0.27	18.50	-0.19	-16.12	0.00	-0.03	-0.01
70	7	7	77.70	8.07	1.67	6.39	0.00	1.00	0.23	18.16	-0.19	-16.12	0.00	-0.03	-0.01
71	7	8	77.70	8.07	1.76	6.30	0.00	1.00	0.20	17.91	-0.18	-16.12	0.00	-0.03	-0.01
72	7	9	77.70	8.07	1.83	6.24	0.00	1.00	0.18	17.72	-0.18	-16.12	0.00	-0.02	-0.01
73	7	10	77.70	8.07	1.88	6.18	0.00	1.00	0.16	17.57	-0.17	-16.12	0.00	-0.02	-0.01
74	7	11	77.70	8.07	1.93	6.14	0.00	1.00	0.15	17.44	-0.16	-16.12	0.00	-0.02	-0.01
75	8	1	77.70	8.07	3.96	4.10	0.00	1.00	0.00	11.66	-0.11	-8.22	0.00	-0.04	-0.01
76	8	2	77.70	8.07	4.73	3.34	0.00	1.00	0.05	9.49	-0.11	-8.22	0.00	-0.09	-0.03
77	8	3	77.70	8.07	4.95	3.12	0.00	1.00	0.00	8.86	-0.11	-8.22	0.00	-0.08	-0.03
78	8	4	77.70	8.07	5.01	3.06	0.00	1.00	0.00	8.68	-0.11	-8.22	0.00	-0.07	-0.02

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

									COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)						
ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
79	8	5	77.70	8.07	5.03	3.04	0.00	1.00	0.00	8.63	-0.10	-8.22	0.00	-0.06	-0.02
80	8	6	77.70	8.07	5.04	3.03	0.00	1.00	0.00	8.60	-0.10	-8.22	0.00	-0.06	-0.02
81	8	7	77.70	8.07	5.04	3.02	0.00	1.00	0.00	8.59	-0.10	-8.22	0.00	-0.05	-0.02
82	8	8	77.70	8.07	5.04	3.02	0.00	1.00	0.00	8.58	-0.10	-8.22	0.00	-0.05	-0.02
83	8	9	77.70	8.07	5.05	3.02	0.00	1.00	0.00	8.58	-0.09	-8.22	0.00	-0.05	-0.02
84	8	10	77.70	8.07	4.94	3.13	0.00	1.00	0.55	8.89	-0.09	-8.22	0.01	-0.05	-0.02
85	9	1	77.70	8.07	4.99	3.07	0.00	1.00	0.00	8.73	-0.09	-8.22	0.00	-0.04	-0.02
86	9	2	77.70	8.07	5.04	3.02	0.00	1.00	0.00	8.59	-0.09	-8.22	0.00	-0.04	-0.01
87	9	3	77.70	8.07	5.06	3.01	0.00	1.00	0.00	8.55	-0.09	-8.22	0.00	-0.04	-0.01
88	9	4	77.70	8.07	5.06	3.00	0.00	1.00	0.00	8.53	-0.08	-8.22	0.00	-0.04	-0.01
89	9	5	77.70	8.07	5.07	3.00	0.00	1.00	0.00	8.52	-0.08	-8.22	0.00	-0.03	-0.01
90	9	6	77.70	8.07	5.07	3.00	0.00	1.00	0.00	8.52	-0.08	-8.22	0.00	-0.03	-0.01
91	9	7	77.70	8.07	5.07	3.00	0.00	1.00	0.00	8.51	-0.08	-8.22	0.00	-0.03	-0.01
92	9	8	77.70	8.07	5.07	3.00	0.00	1.00	0.00	8.51	-0.08	-8.22	0.00	-0.03	-0.01
93	9	9	77.70	8.07	5.07	2.99	0.00	1.00	0.00	8.51	-0.07	-8.22	0.00	-0.03	-0.01
94	9	10	77.70	8.07	5.07	2.99	0.00	1.00	0.00	8.50	-0.07	-8.22	0.00	-0.03	-0.01
95	9	11	77.70	8.07	5.07	2.99	0.00	1.00	0.00	8.50	-0.07	-8.22	0.00	-0.03	-0.01
96	9	12	77.70	8.07	5.07	2.99	0.00	1.00	0.00	8.50	-0.07	-8.22	0.00	-0.03	-0.01
97	10	1	77.70	8.07	0.80	7.27	0.00	1.00	1.64	20.66	-0.05	-6.04	0.02	-0.08	-0.03
98	10	2	77.70	8.07	3.73	4.34	0.00	1.00	0.82	12.33	-0.05	-6.04	0.01	-0.06	-0.02
99	10	3	77.70	8.07	4.61	3.46	0.00	1.00	0.54	9.82	-0.05	-6.04	0.00	-0.05	-0.02
100	10	4	77.70	8.07	4.99	3.08	0.00	1.00	0.41	8.74	-0.04	-6.04	0.00	-0.04	-0.01
101	10	5	77.70	8.07	5.20	2.87	0.00	1.00	0.33	8.15	-0.04	-6.04	0.00	-0.04	-0.01
102	10	6	77.70	8.07	4.50	3.57	0.00	1.00	2.30	10.13	-0.21	-6.04	0.04	-0.35	-0.33
103	10	7	77.70	8.07	5.52	2.55	0.00	1.00	0.04	7.24	-0.19	-6.04	0.00	-0.34	-0.14
104	10	8	77.70	8.07	5.64	2.42	0.00	1.00	0.03	6.89	-0.18	-6.04	0.00	-0.32	-0.11
105	11	1	77.70	8.07	0.00	8.07	0.00	1.00	3.27	22.92	-0.05	-12.09	0.02	-0.09	-0.03
106	11	2	77.70	8.07	1.47	6.59	0.00	1.00	4.36	18.73	-0.24	-12.09	0.04	-0.18	-0.51
107	11	3	77.70	8.07	3.08	4.98	0.00	1.00	0.05	14.15	-0.23	-12.09	0.00	-0.25	-0.17
108	12	1	77.70	8.07	5.68	2.39	0.00	1.00	0.01	6.79	-0.18	-4.84	0.00	-0.30	-0.11
109	12	2	77.70	8.07	6.00	2.06	0.00	1.00	0.01	5.86	-0.18	-4.84	0.00	-0.30	-0.10
110	13	1	77.70	8.07	5.50	2.56	0.00	1.00	0.00	7.28	-0.09	-4.11	0.00	-0.09	-0.03
111	13	2	77.70	8.07	6.26	1.81	0.00	1.00	0.00	5.14	-0.09	-4.11	0.00	-0.09	-0.03
112	13	3	77.70	8.07	6.42	1.64	0.00	1.00	0.00	4.66	-0.09	-4.11	0.00	-0.09	-0.03
113	13	4	77.70	8.07	6.46	1.60	0.00	1.00	0.00	4.55	-0.08	-4.11	0.00	-0.08	-0.03

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY) F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
114	14	1	77.70	8.07	0.00	8.07	0.00	1.00	1.64	22.92	-0.20	-16.12	0.01	-0.08	-0.03
115	14	2	77.70	8.07	0.00	8.07	0.00	1.00	0.81	22.92	-0.19	-16.12	0.00	-0.06	-0.02
116	14	3	77.70	8.07	0.59	7.47	0.00	1.00	0.54	21.23	-0.18	-16.12	0.00	-0.05	-0.02
117	14	4	77.70	8.07	1.10	6.97	0.00	1.00	0.41	19.80	-0.18	-16.12	0.00	-0.04	-0.01
118	14	5	77.70	8.07	1.37	6.69	0.00	1.00	0.33	19.02	-0.17	-16.12	0.00	-0.04	-0.01
119	14	6	77.70	8.07	1.55	6.52	0.00	1.00	0.27	18.52	-0.16	-16.12	0.00	-0.03	-0.01
120	14	7	77.70	8.07	1.67	6.40	0.00	1.00	0.23	18.17	-0.16	-16.12	0.00	-0.03	-0.01
121	14	8	77.70	8.07	1.76	6.31	0.00	1.00	0.20	17.92	-0.15	-16.12	0.00	-0.03	-0.01
122	14	9	77.70	8.07	1.83	6.24	0.00	1.00	0.18	17.72	-0.15	-16.12	0.00	-0.02	-0.01
123	14	10	77.70	8.07	1.88	6.18	0.00	1.00	0.16	17.57	-0.14	-16.12	0.00	-0.02	-0.01
124	15	1	77.70	8.07	5.76	2.31	0.00	1.00	0.00	6.56	-0.08	-4.11	0.00	-0.08	-0.03
125	15	2	77.70	8.07	6.36	1.71	0.00	1.00	0.00	4.86	-0.08	-4.11	0.00	-0.08	-0.03